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COMMERCIAL Space

THE MAGAZINE OF BUSINESS IN SPACE

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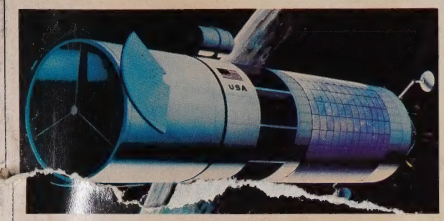

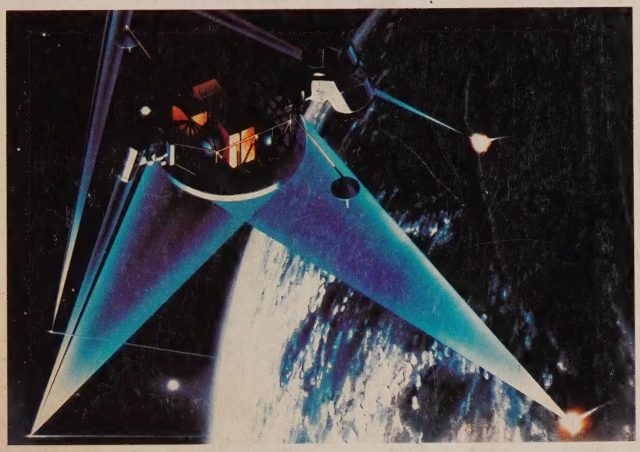

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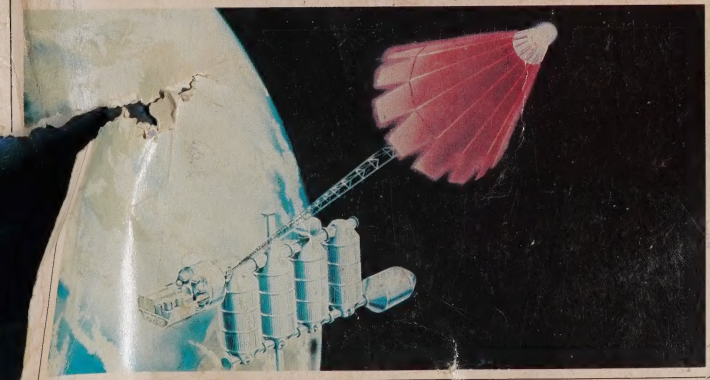

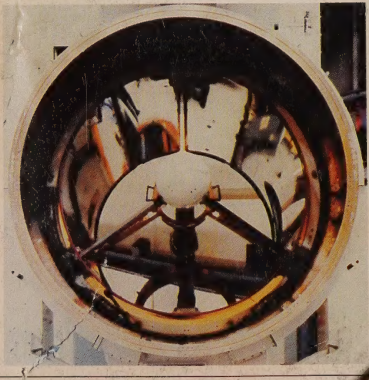

In 1992, we set sail for a New World.

In 1492, a Genoese navigator and an intrepid crew crossed uncharted waters in search of a west passage to India. In the process, they uncovered the vast resources of two continents. And they opened up a new base for exploration, progress, and the hopes of mankind.

In 1992, coincident with the 500th anniversary of Columbus's voyage, we plan to set sail for another New World. That year, or shortly thereafter, the United States and the world will begin benefiting from the first manned Space Station. The Station will be more than another giant step for mankind. It will be our stepping stone to living in new realms, and it will result in thousands of discoveries that will benefit earth.

This New World, free from gravity and atmospheric impurity, will provide that ideal environment for experimentation and production that is impossible on earth. Simultaneously we will have a permanent station for scanning the earth and the heavens—an unparalleled vantage point for predicting weather, aiding agriculture, and understanding the universe.

Of course, like Columbus, we cannot foresee all the benefits ahead. But we do know that we will have a new arena in which to conquer disease, transform the materials of earth, and generate precious energy. The resulting knowledge from countless discoveries will come down to earth for our well-being.

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Now Harris is ready for the Space Station. Over the next years and centuries, the scope of scientific, commercial and technological opportunities and breadth of results are sure to exceed our wildest expectations.

For in 1992, we, too, will be very much like Columbus: carrying the sum of our knowledge into the unknown. And, like him, we, too, shall return with the bountiful gifts of a New World.

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COMMERCIAL Space
SPRING 1986 THE MAGAZINE OF BUSINESS IN SPACE

U. S. space program is in turmoil following the Challenger, Delta and Titan accidents, but the Strategic Defense Initiative offers a billion-dollar business potential for small and large companies to get in on the cutting edge of a range of new technologies. To illustrate this, our art director, Moumtaz Joukhadar, assembled a collection of SDI concepts to create this issue's cover. The story starts on page 18.

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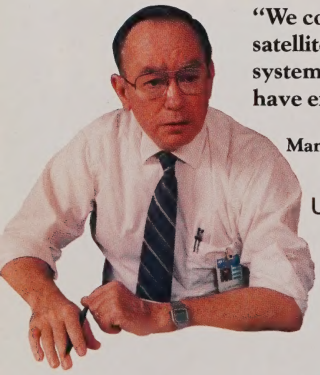

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TECHNOLOGY PREVIEW

THERE'S NO SUBSTITUTE FOR MAN IN SPACE, ACCORDING TO A MCDONNELL DOUGLAS STUDY

A recently completed twenty-six-month McDonnell Douglas study has concluded that there is no substitute for man in space. The $500,000 study, funded by the National Aeronautics and Space Administration's Marshall Space Flight Center, was performed to investigate the role of humans in space and develop guidelines for the best use of man and machine.

The study, called "The Human Role in Space" (THURIS), found that man was the most cost effective way to deploy and assemble large structures, man's ingenuity and flexibility is needed in space to repair and maintain machinery, man's abilities are needed in laboratories performing space experiments, and man's versatility is very useful for performing everyday chores in space. The conclusions of the study were based upon analysis of fifteen past and future space missions using the guidelines developed by the study.

As supporting evidence, THURIS cited that astronauts on the first shuttle mission were able to repair a failed camera after receiving instructions from ground-based personnel. The study also estimated the cost of a self-deploying orbiting platform at $2.4 million, while a similar astronaut deployed structure would cost one-tenth as much.

THURIS did conclude, however, that machines are better at some jobs, particularly those involving excessive information processing and numerical computation.

Areas for machine use on the space station identified by the study included system monitoring, logistics and inventory control and storage of detailed equipment repair procedures. ●

HAMILTON STANDARD WILL DEVELOP A DIGITAL HELMET-MOUNTED DISPLAY SYSTEM

Development of a digital electronics helmet-mounted display system to provide visual instructions and information to astronauts working in space will be pursued by Hamilton Standard through a $1.1-million National Aeronautics and Space Administration award.

The helmet-mounted display will enable astronauts to receive information from the space suit's built-in computer, the space shuttle and mission control using voice-activated controls. The information expected to be available to the astronaut includes space suit life support system data, and text, illustrations and diagrams that will provide astronauts with prompt and extensive data to aid them in the performance of their duties.

The purpose of the system is to decrease astronaut ground training time and increase astronaut flexibility.

Stanley W. Kandebo/New York

"Right now, an astronaut has to undergo a long training period to become an expert on the particular piece of equipment that he'll be working on in space," Alfred Brouillet, Hamilton Standard chief-advanced systems, space and sea systems department, said. "The helmet-mounted display will reduce this training time since it will furnish the astronaut with the detailed instruction necessary to complete the extravehicular activity task at hand. In addition, it will allow the working astro-

naut access to manuals, diagrams and other material to help him through any difficulties if complications arise."

Incorporation of a voice interactive system into the helmet-mounted display will decrease astronaut workload and extend the effective reach of the astronaut. Mounted on the chest of the current space suit is a 4-in.-thick box called the display and control module. It contains suit environmental controls, displays and switches. Combining the helmet-mounted display with a voice interactive system means that the control box can be eliminated.

"If an astronaut wants to increase the amount of cooling provided by his controls, he now adjusts a valve. In the future, the astronaut would command the suit to get cooler, and additional cooling would be supplied on his voice command," Brouillet said. Elimination of the display and control module will also allow an astronaut to get four inches closer to his work.

Delivery of a flight rated prototype helmet incorporating a display, voice recognition and activation system and voice synthesis system is expected to be made to the Johnson Space Center in the summer of 1987. Additional work examining the application of the voice interactive communication technology to other areas of the space station program also is expected. ●

CONSORTIUM WINS BID TO BUILD COMMUNICATIONS SATELLITE

A European consortium led by France's Aerospatiale has won the competition to build a series of second-generation satellites (shown here) for the multinational Eutelsat telecommunications organization. The award is one of the largest contracts for operational communications satellites ever placed with European industry.

The $217-million order is for three Eutelsat 2 spacecraft. An option for five additional satellites was also placed.

The Aerospatiale-led consortium proposed a satellite based on the Aerospatiale/MBB-Erno Spacebus 100 design. Spacebus 100 previously was used as the configuration for the Arab League's Arabsat communications/TV distribution satellite. The Spacebus 100 design employs

Competitiveness and performance

composite materials, including a graphite-epoxy/light alloy honeycomb spacecraft central cylinder that transmits satellite loads and houses the propellant tanks; graphite epoxy frames for the rigid solar arrays, and a flexible Kapton skin reinforced with carbon fiber to which the solar array's solar cells are bonded.

Participating with Aerospatiale and West Germany's MBB-Erno in the winning Eutelsat consortium are the United Kingdom's Marconi, France's Alcatel-Thomson Espace, Italy's Aeritalia and Sweden's L. M. Ericsson.

Eutelsat 2 spacecraft will be able to simultaneously provide relay services on 16 channels for European coverage with telephone, television, data transmission and business services. Launch of the first Eutelsat 2 is planned for mid-1989, for replacement of the current Eutelsat 1 series of satellites. ●

U. S. SPACE AGENCY RECEIVES 25 BIDS FOR SPACE CENTERS

The second NASA solicitation to establish additional Centers for the Commercialization of Space has resulted in the receipt of 25 proposals by the agency. Selection of successful candidates is expected in June or July, and could result in the creation of an additional seven centers.

Five centers were established last August in the areas of macromolecular crystallization, materials development, space development of engineering materials, remote sensing and multiphase materials.

Under the terms of the recent solicitation, approximately $750,000 will be provided to each newly created center for five years. Annual funding levels of the centers will be related to yearly performance reviews.

The proposals requested by NASA were in ten areas it identified as promising for commercial space ventures. These areas included: electronic materials, biotechnology, fluid dynamics, glass and ceramics, metals and alloys, chemistry and physics processing, associated process control technology, earth and ocean observation, communications, life sciences, space technology and materials processing. Proposals in other areas were also accepted. ●

FRENCH REVIEW ESCAPE DEVICES ON ARIANE AND HERMES FOLLOWING CHALLENGER LOSS

France plans to review the design of its Ariane 5 heavy-lift launcher and closely examine escape/rescue measures for the Hermes spaceplane following the destruction of the National Aeronautics and Space Administration's space shuttle Challenger earlier this year.

The Ariane is expected to become operational in the latter part of the 1990s and will be powered by a pair of segmented solid rocket boosters and a central cryogenic engine.

The primary mission of the launcher will be to place unmanned payloads in geostationary or low Earth orbit. It will also be used to launch the Hermes spaceplane into orbit.

Ariane engineers will study the sizing and thickness of segment joints for the launcher's solid boosters to ensure that the deformation that occurs at booster ignition does not lead to the type of failure that is suspected to have contributed to the Challenger loss. Vehicle system safety will also be examined as part of the study.

According to Frederic d'Allest, director general of the French CNES space agency, the Ariane launcher program is in a sufficiently early stage to incorporate easily any changes or modifications that are judged to be necessary.

CNES is overseeing the Ariane 5 program, with lead development for the launcher assigned to Aerospatiale. Aerospatiale and Dassault-Breguet are cooperating on the design and manufacture of the Hermes spaceplane. ●

with Ariane/Sylda

Ariane, the European booster, is manufactured by forty companies in eleven countries. Ariane's architect?
Aerospatiale. Studies, system testing, industrial conception of the rocket's stages, technical management, integration.
Aerospatiale also manufactures the double launch system SYLDA.
This component increases Ariane's competitiveness by allowing the simultaneous injection into orbit of two middle-size satellites.

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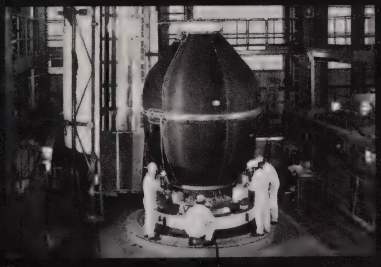

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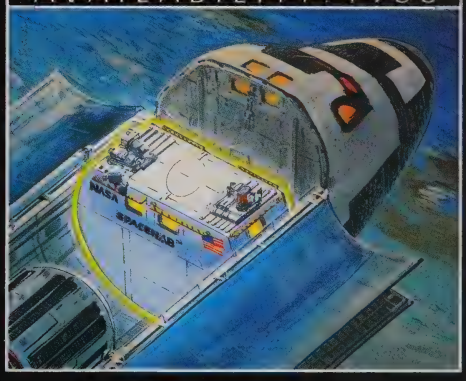

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WASHINGTON OVERVIEW

This city of perpetual debate is about to enter a long new chapter of contention about space policy: whether the nation should attempt permanent colonization of the Moon and Mars in the first two decades of the 21st century.

A blueprint prepared by the National Commission on Space is ready and the President almost certainly will approve it. He probably will order it thoroughly studied, leaving space analysts and policymakers to grope their way through the perennial host of Washington questions that, depending on one's point of view, usefully thresh out or needlessly afflict issues of great moment.

Most of the space community can be expected to endorse the blueprint's ideals, its majestic vision of the inner solar system as humankind's rightful habitat. Endorsements in principle aside, the political questions will take over. The transcendent one is "Who benefits, who not?" but a multitude will be subjoined: is the blueprint too bold, too timid, too costly? Who will finance it, who carry it out? Will it rob the poor and swell the rich? Does the public like it, will the public support it?

Further: can a plan for half a century, stretching to the year 2035, be sustained unremittingly over five decades in the face of uncertain budgets, unstable economies, competing programs, fast-changing technology, multiple administrations, fickle legislatures, inert bureaucracies and—not least—ruthless political infighting?

And those are just the domestic considerations. How ferocious will international conflicts be, legal or otherwise, when nations clash in space over solar system real estate, squatters' rights, mineral resources and air space?

"Human nature will flow wherever humans are," admonishes Dr. Robert K. Vincent, head of Geospectra Corp., a remote sensing company in Ann Arbor, Michigan.

These and other concerns will flow naturally from the commission's ambitious recommendations. Appointed in March, 1985, by President Reagan, the commission was mandated by Congress to devise a comprehensive civilian space agenda. The results are contained in a pending 200-page report, Pioneering the Space Frontier, Our Next Fifty Years in Space. The report postulates expenditures of at least $700 billion between 1995 and the year 2020. Much of the money would be spent on three new cargo and passenger vehicles, on interplanetary factories and on permanent spaceport service-and-supply depots that would follow up the space station, which the commission assumed would be operational in 1995.

The commission is chaired by Thomas O. Paine, former administrator of the National Aeronautics and Space Administration. Vice chairman is Laurel L. Wilkening, a planetary scientist and vice provost of the University of Arizona. Members include Neil A. Armstrong, first man to step on the Moon, Kathryn D. Sullivan, geologist and astronaut, and USAF Brig. Gen. Charles E. Yeager, ret., first pilot to fly faster than the speed of sound.

"The concept of a national commission began in the Congress because, for all of our technological success, there was a failure of vision in regard to our future in space," remarked Rep. Robert G. Torricelli (D.-N. J.), a member of the House Science and Technology space science and applications subcommittee. "America had a space program headed in all directions and no direction. This blueprint generally contains what I had hoped. We have to accept the inevitable challenge of interplanetary travel."

Proposals for full-scale lunar and Martian settlements by 2017 and 2027, respectively, come as no surprise to space experts here. One, John E. Pike, associate director for space policy of the Federation of American Scientists, said an even bolder idea—an unmanned probe to the nearest star, Alpha Centauri—would have improved the commission's chances for rallying public support.

An Alpha Centauri mission would cost billions and require a hundred years of flight time, Pike said, but, "a starship is a nice, sexy, long-term goal that would galvanize public opinion." Without such a goal, he worries, the public won't bring to bear the political pressure on Congress necessary to enact the commission's agenda.

"What's the payoff?—that's the public's question," Pike said. "The payoff is too intangible. I think the bottom line is that the country's made a political decision that people who want to play with rockets are going to get $7 billion a year [the amount of NASA's budget], but no more than that. That seems to be about all the traffic will bear."

John M. Logsdon, director of the graduate program in science, technology and public policy at George Washington University here, is inclined to agree. Based on National Science Foundation material, he said, public support for long-range space exploration is ambivalent. "People like space, it clearly strikes a responsive chord in the American psyche, but if you say, 'Here's what it's going to cost,' I wonder whether it scares people away. It does seem to me that carving out a vision of the future in space that garners public support is a job for the President, and the commission's report gives the President a leadership opportunity. This President seems to want that."

Even if public enthusiasm is shallow, the commission's report nonetheless is thought susceptible to accentuating the politically positive. Geospectra's Vincent points out that the report by nature is bipartisan and, if enacted, will long outlive any administration, Republican or Democrat.

"Nobody will get famous for it, but by the same token nobody will take a beating over it," he said. "It's a higher calling, politically speaking, a higher calling that transcends partisan bickering, and I think it is one the American people will support. As a taxpayer, I've been looking for something free of politics-as-usual that we could shoot for. This is a psychological boost, to shoot for things beyond our own immediate welfare, even though we have short-term differences. The human community is happiest when it's got a frontier to work on. It lowers our aggressive tendencies toward one another and directs them toward nature, which is the ultimate adversary anyway, as far as existence goes. I strongly believe that for the psychological welfare of the human community, we have to have physical frontiers to develop."

Yet it's an open question whether presidential leadership and the commission's idealism can combine to overcome large institutional hurdles to so broad a commitment. Gregg R. Fawkes, director of the space enterprise project for the National Chamber Foundation, believes government's handling of lengthy commitments is getting worse, not better, and basic is-

Paul Mann/Washington

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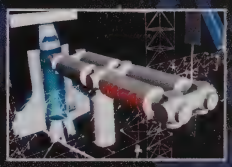

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sues will have to be dealt with if the commission's program is ever to be realized. He is particularly concerned about the unwillingness of Congress to commit funds for more than a year at a time, a perennial problem exacerbated now by the government's massive debt.

"What we're seeing more and more of is roller-coaster funding and congressional micromanagement," Fawkes laments, "with constant changes of course and direction. I'd love to see the nation credibly commit to a program like this, but I don't think any knowledgeable observer thinks that's possible in the current environment. There will have to be some sort of structural change in congressional procedures so that there is a certain class of programs and commitments that we pursue over a long period of time with continuity."

Stable funding does not mean sufficient funding, though, and views differ about whether the money can be found. Pike, for example, argues both ways. He believes the U. S. "can afford to do anything it wants to." That would include both the commission's agenda and President Reagan's program for ballistic missile defense, the Strategic Defense Initiative, which by one estimate will cost a trillion dollars. Yet he also acknowledges that when people look at the commission's blueprint, they'll say, "We're not going to spend that kind of money. It's unrealistic in fiscal terms."

William R. Claybaugh, a private investor in space projects and vice president of the space division at University City Science Center, Philadelphia, agrees.

"Right now the government cannot afford the infrastructure we need to go ahead in space," he said. "It seems obvious to me then that the federal government ought to set up structures to encourage private sector funding. That raises the really fundamental issue of who controls the space program. To the extent we wish it to be centrally planned, government funding is the way to go. If we want to make the rest of the American economy vibrant, then we should let the private sector do it."

In its report, the commission suggested NASA have a role in encouraging new space enterprises, stating: "It is imperative that the private sector be much more heavily involved in defining the nature and specifications of future launch vehicles. This will help insure the adoption of commercial practices that will reduce operating costs and make it possible to transfer operation of these vehicles to the private sector."

In general, the commission calls for exploring, prospecting and settling the inner solar system, and favors the Earth-Moon region for initial industrial production.

It also said the two most significant contributions government can make are ensuring continuity of launch services and drastically reducing transportation costs.

"That's true," responded David W. Lippy, president of the Center for Space Policy, Inc., a space business consulting firm in Cambridge, Mass. "But where's the funding going to come from in advance of that, to make that happen? There is no development in the report of how we get Fortune 500 companies involved in the space program. I looked at the report as an important wish-list but I didn't see establishment of a specific set of priorities. It ignores fiscal realities and omits an implementation plan."

Logsdon, of George Washington University, said the commission's language regarding private enterprise should be interpreted with care. "My reading says that this is really about human destiny, that the motivation underpinning the recommendations is an act of faith proper. The motivations for man to want to live and work in places off this planet are not primarily economic, in terms of adding to the gross national product on Earth. The report's discussion of economics is aimed mostly at trying to make what happens in space economically self-sufficient, so that it doesn't drain money from Earth. The role of the private sector is, as far as I can tell, to provide services to government-funded operations. Despite all the rhetoric about the private sector, this isn't really private sector stuff, it's not aimed at developing markets and I'm not so sure that Wall Street is relevant. If it's government that leads this thrust, it's government that's going to pay for it."

> 'There is no development in the [National Commission of Space's] report of how we get Fortune 500 companies involved in the space program'

The short-term economic implications are not very significant, Logsdon believes, because it will cost relatively little the next five years to embrace the program, excepting the expense of the space station. With respect to investments in second-generation space transporters, "We'll probably do that for the Strategic Defense Initiative anyway," he said.

In contrast, Congressman Torricelli inverted the two. If the commission's objectives are not achieved, neither will SDI's, he said, asserting: "They are not separate questions. I'm against SDI, but the technology offered by the commission would be crucial to SDI capability. But SDI's costs are so enormous that they are a threat to each investment of the federal government. They can crowd out many scientific and military programs."

Regarding interplanetary law, the commission took the view that existing United Nations treaties ratified by the U. S. provide a sufficient legal framework for future uses of space. However, it recommended that the U. S. avoid accepting international arrangements that give broad jurisdiction over American space activities to international bodies in which adversaries have undue influence or in which decisions will be made by majorities with little current competence in the space field.

In addition, it recommended against U. S. support for any global organization that purports to regulate broadly the utilization of outer space. It complained that some international institutions, namely the International Telecommunications Union (ITU) and United Nations organs such as the General Assembly and the Committee on the Peaceful Uses of Outer Space (COPUOS), have become increasingly politicized. It said the U. N.'s one nation/one vote principle gives the controlling majority to countries with no current capability in space exploration. Furthermore, "The system of bloc politics that prevails in the United Nations results in extraneous issues such as the Arab/Israeli dispute, intra-African differences and East/West rivalry intruding into space policy decisions. The strength of the Soviet Union in the United Nations (via its client states) gives it more influence on U. N. decisions than is enjoyed by the United States and other democracies."

As for the character of permanent lunar and Martian installations, the commission said, "Human settlements, not national colonies, should be the model. These new communities would allow a revival of cultural diversity that now seems threatened on Earth." Yet, in its statement of rationale, the commission struck what Professor Logsdon construed as an extremely nationalistic note. It declared, "With America's pioneer heritage, technological preeminence and economic strength, it is fitting that we should lead the people of this planet into space."

The commission's assumption is, Logsdon said, that American values and the American system will be projected onto the other bodies of the solar system. "One wonders what the Europeans, the Chinese, the Soviets and the Japanese will think of that vision. Yes, the colonies might be international in composition, but they would operate under the rules of pluralistic democracy in the United States and be based on free enterprise." ●

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Donald E. Fink/New York

EXPANDING BUSINESS OPPORTUNITIES

EDITORIAL

With the U. S. space program in an obvious state of turmoil, the global business community has good cause to seek some interpretation of how the recent series of launch failures will affect the future development of space business. What is needed first, however, is a clear definition of what constitutes such space business opportunities. In its attempts to generate broader participation in space activities by the commercial business world, the National Aeronautics and Space Administration has emphasized the benefits that can be gained from transporting earthbound products or manufacturing processes into space and adding value by capitalizing on the unique environment—microgravity, near vacuum and extremes of heat and cold—found in orbit.

Excellent progress had been made in the early stages of the space shuttle program toward developing procedures, using such elements as the McDonnell Douglas electrophoresis experiment and the Marshall Space Flight Center's numerous materials processing and space manufacturing projects, to form the basis of such an all-new high-value business.

Unfortunately, the Challenger accident in January has forced a standdown in shuttle operations until next summer. This has made a shambles of NASA's payload manifest and raises concerns about shuttle as a commercial launch system.

Even after the technical and management problems that contributed to the Challenger accident are solved—as they most surely will be—loss of one of the four orbiter vehicles means that NASA will be hard pressed to regain the operational commercial mission pace it had hoped to achieve this year.

These uncertainties will not disappear overnight and have to cause concern for businessmen looking to space for new investment opportunities. However, as crucial as the shuttle is to near-term development of commercial space opportunities—those based on products that need to be delivered to space and returned and that require man-in-the-loop in orbit—the reusable system is not the only element in the equation. Expendable launchers have a role to play in orbiting commercial payloads, as has been demonstrated for years with communications satellites and more recently in Earth resources applications.

NASA's recent Delta launcher accident and the Air Force's loss of two Titan 34D launch vehicles in a row do little to enhance the image of expendable launchers, however, and serve to point out the tenuous nature of the early efforts to commercialize space. But none of these setbacks negates the long-term viability of the U. S. space program any more than airplane accidents in the early 1900s stopped the development of commercial aviation. What they do is highlight the need for the National Aeronautics and Space Administration to tighten its technical, management and quality control procedures and quickly put its primary programs back on track.

There still are a number of on going space business opportunities—such as the Strategic Defense Initiative to develop a technical foundation for a space-based intercontinental ballistic missile defense system—being pursued in the U. S. As outlined in this issue of Commercial Space, SDI represents a billion-dollar business potential.

By its nature, SDI primarily involves large aerospace companies as its prime contractors, but the program also represents opportunities for small- to medium-size companies to get in on the cutting edge of a range of technologies. An impressive list of contractors already at work on SDI projects appears on page 20. If, when the technology development phase is completed, a decision is made to field an SDI system, that list will expand enormously.

Even if a fully operational antimissile system is not fielded, technical progress achieved under SDI will stimulate untold new opportunities for businessmen astute enough to understand that advanced technology is a highly marketable entity, often in applications not remotely associated with the programs under which it was developed.

NASA has had considerable success in fostering this kind of technology spinoff from its space programs. The agency currently is funding a variety of developmental activities under the space station program. And in the past, through its technology utilization effort, NASA succeeded in priming many an entrepreneurial pump by taking new ideas and techniques from its space programs and helping industry find ways to develop them into commercially salable products.

Commercial space opportunities are not found only in orbit. Nor are they tied to any category of programs, whether they be civilian or military. A great deal of space business has been, and will continue to be, done by the astute investor who sees and pursues his opportunities on terra firma. ●

SDI HAS ALREADY PROVED A $6-BILLION OPPORTUNITY FOR MANAGERS TO REAP PROFITS FROM

DEFENSE BUSINESS

Theresa M. Foley/Washington

The Strategic Defense Initiative research program, while spending billions of dollars to develop technology for possible future space-based weapons, may bring unexpected side benefits to commercial and terrestrial industries that are positioned to capitalize on SDI technology spinoffs or to serve as subcontractors or suppliers.

Steps are being taken now within SDI management to allow U. S. industry to capitalize on SDI technology transfer in the same way that civilian space projects have stimulated terrestrial economic growth for years. Hundreds of new products were introduced in the United States by creative commercial enterprises as a result of the $24 billion the National Aeronautics and Space Administration spent on the Apollo program in the 1960s and 1970s. SDI holds the same potential. Billions more will be spent on SDI in the coming years, and while much of that money will go to the traditional defense industry, a significant amount is likely to end up with small business and non-defense firms.

"What if free people could live secure in the knowledge that their security did not rest upon the threat of instant U. S. retaliation to deter a Soviet attack; that we could intercept and destroy strategic ballistic missiles before they reached our own soil or that of our allies?"

Placing that question before the American public on Mar. 23, 1983, President Reagan embarked on the controversial, multibillion research program officially known as the Strategic Defense Initiative and often referred to as Star Wars. Although SDI may eventually lead to the deployment in space of dozens or hundreds of weapons that could defend against nuclear missile attack, the currently structured program does not represent a decision to deploy such a system.

Green shading over California indicates its rank as No. 1 among the 50 states in Strategic Defense Initiative contracts, with over $2.6 billion. Six states, shown in orange, have over $100 million in SDI contracts. States shown in tan have contracts valued at between $1 billion and $100 billion. Urban areas drawing more than $10 million in SDI business are designated with red dots. Los Angeles area businesses boast $1.5 billion in SDI contracts.

Instead, the Defense Department has undertaken an intensive research and development program that is resulting in the expenditure of billions of dollars on promising technologies that might allow an effective shield to be deployed in the coming decades. Much research in SDI-related areas had begun before Reagan announced the new program, which has created a central organization for the technology efforts and drawn enormous public attention.

A ballistic missile defense system would need multiple layers of defense to have any hope of destroying all attacking missiles.

The Strategic Defense Initiative is organized into five main technical areas:

- **Surveillance, Acquisition, Tracking and Kill Assessment,** known also as SATKA. Sensors would detect the launch of attacking missiles, identify and track them. A key problem in this area is developing a method for sensors to tell the difference between decoys and real warheads. Kill assessment will determine whether a target missile has been knocked out so that resources are not wasted by expending effort on targets that already have been killed.
- **Directed energy.** Weapons based on this technology would use directed energy, such as lasers or particle beams, to destroy an attacking missile. A laser, which stands for light amplification by stimulated emission of radiation, creates an intense, single-wavelength beam of light.
- **Kinetic energy.** Weapons based on this technology would use a projectile or other object moving at a very high speed to knock out an attacking missile.
- **Battle management and command, control and communications.** Technologies in this area allow information to be processed and decisions to be made. Because a nuclear attack would allow only a few minutes to make a response decision, highly reliable automated equipment would be needed to control the system with minimal human involvement.
- **Survivability and lethality.** SDI weapons will require protection from attack, so a strong effort is being undertaken to develop the means to safeguard the system from enemy attack. Lethality is aimed at determining the damaging effects of various weapons that might be deployed in an SDI system and target hardening attempts to determine what countermeasures might be taken to protect the attack missiles from being knocked down by SDI.

The Strategic Defense Initiative program has awarded more than $6 billion in contracts since it started in 1983, and it is expected to offer excellent future business opportunities for industry, universities and national laboratories. Contractors—including for-profit companies and non-profit organizations—stand to reap billions of dollars in SDI awards every year.

While entrepreneurs and nondefense contractors may not have much chance of winning large SDI contracts, they may be assisted by a new technology transfer program that SDI is establishing. The program would help commercial users obtain unclassified SDI-related technology to develop new products. The technology

Technician at Lawrence Livermore National Laboratory works on one of 190 accelerator modules of the advanced test accelerator, which is used in research on free-electron lasers for the Strategic Defense Initiative.

transfer program, in the early planning stages now, could be available by the end of 1986, Col. James A. Ball, SDI deputy director for civil applications, said.

If the program is approved, SDI-developed technologies will be reviewed to identify those with potential industry applications. Abstracts describing technology that may be useful will be stored in a data base that can be accessed by persons or companies on the qualified U. S. contractor list. Access to the data base will be restricted to persons or organizations that have signed a military critical technology data agreement certifying that the information will be used for legitimate business purposes and will not be transferred to a foreign entity.

Within a year, there may be as many as 1,000 entries in the data base, according to Ball. Although Ball could not cite examples of technology that will be in the SDI data base, he described civil applications that have grown out of other Defense Department technology transfer programs. Technology for a spinal bypass technique that can help paraplegics walk was spun off from a Navy antisubmarine warfare program. Laser technology frequently has been applied to medical procedures and advanced composite technology has been used to develop new materials for sporting goods such as skis.

The technology in the data base will be developed by government laboratories or companies receiving SDI funding.

An analysis of SDI contracts shows that most of the money is going to a handful of organizations that are located in a few concentrated geographical pockets of the United States. The SDI budget, at $4.8 billion in Fiscal 1987, is still well below either the National Aeronautics and Space Administration or the Air Force space budgets. But the faster growth of the SDI budget, which climbed from $1.4 billion in Fiscal 1985 to $2.8 billion in Fiscal 1986 and $4.8 billion in Fiscal 1987, could boost SDI far ahead of other government space organizations in terms of contracting power in the coming years. SDI is a favorite of President Reagan and has been exempted from the Gramm-Rudman-Hollings deficit reduction bill.

In a time when many space projects and some areas of U. S. leadership in aerospace technology are being threatened by severe budget cutbacks, the SDI organization is overseeing technology development budgets that have almost doubled every year in the last few years.

Chart below was compiled by the Federation of American Scientists. Amounts include funds that have been obligated over the last three fiscal years, that are obligated in future years and some priced contract options still to be exercised. In listing Lawrence Livermore at the top, FAS estimates Livermore will receive $500 million for a free electron laser to be built over the next three years.

SDI OFFERS SPACE-BASED BILLION-DOLLAR BONANZA

UNIVERSITIES, RESEARCH FIRMS AND PRIVATE ENTERPRISE CASH IN ON SDI

RECIPIENT	1983-86 CONTRACTS
DOE Lawrence Livermore	$725,257,000
General Motors	$578,807,751
Lockheed	$520,524,798
TRW	$354,166,146
McDonnell Douglas	$349,773,029
Boeing	$346,215,059
DOE Los Alamos Lab	$195,961,000
Rockwell International	$187,750,235
Teledyne Inc.	$179,722,886
EG&G	$139,600,000
Gencorp Inc.	$134,794,466
Textron	$92,796,098
DOE Sandia Labs.	$91,330,000
LTV Corp.	$90,417,238
Flow General	$89,284,179
Raytheon Co.	$72,049,148
Science Applications	$69,136,451
Honeywell	$68,541,289
Nichols Research	$63,477,099
MIT Lincoln Lab	$63,069,000
Westinghouse Electric	$62,589,274
Martin Marietta	$55,837,850
Litton Systems	$46,947,276
DOE Hanford National Lab	$40,000,000
BDM International	$38,834,105
Utah State Univ.	$38,156,373
Grumman	$37,439,827
Univ. of Texas	$33,232,692
Burroughs	$32,504,111
General Dynamics	$32,290,350
General Electric	$31,305,629
Ford Motor	$30,059,852
W. J. Schafer	$29,265,451
Kaman Sciences	$29,110,692
Sparta Inc.	$28,007,873
United Technologies	$27,848,878
Georgia Inst. of Tech.	$27,218,594
Western Research	$25,413,960
AF Weapons Lab	$22,977,000
Stanford University	$22,247,164
Logicon	$21,894,812
Dynetics Inc.	$20,871,835
Atlantic Research Corp.	$19,577,465
Ashland Oil	$19,100,000
Charles S. Draper Labs	$18,322,376
Morton Thiokol	$16,437,046
Mission Research	$15,959,721
SRS Technologies	$15,421,574
Control Data Corp.	$13,956,917
Army Corps of Engineers	$13,698,000
AF Geophysics Lab	$13,190,000
Computer Sciences Corp.	$12,581,628
Adaptive Optics	$12,073,080
Physical Research	$12,066,898
Mass. Gen. Hospital	$11,950,000
New Technology Inc.	$11,371,842
NASA	$11,130,000
Verac Inc.	$10,723,271
Perkin Elmer	$10,699,490
SRI International	$10,544,802
Riverside Research	$10,434,518
Maxwell Laboratories	$10,135,138
UK Atomic Energy Auth.	$10,000,000
Naval Research Laboratory	$9,874,333
AF Space Command (BMO)	$9,800,000
Allied Signal	$9,779,618
Hercules	$9,421,114
IBM	$9,284,725
E-Systems	$9,283,854
Army BMD Adv. Tech. Center	$9,201,000
U.S. Philips Trust	$8,748,104
GT Devices	$8,661,846
GA Technologies	$8,248,298
Delta Research Inc.	$8,037,217
Colsa Inc.	$8,005,444
Goodyear	$7,903,756
Aeromet	$7,825,946
Applied Technology Assoc.	$7,459,282
PDA Engineering	$7,349,000
Automated Sciences Group	$7,110,929
Univ. of California	$6,876,960
System Planning Corp.	$6,686,416
Texas Instruments	$6,254,183
AF Electronic Systems Div.	$6,119,000
Inst. for Defense Analysis	$5,883,000
Univ. of Dayton	$5,869,108
Sperry Corp.	$5,844,808
Technology Development	$5,829,056
Acurex Corp.	$5,679,416
Army Missile Command	$5,596,000
Battelle	$5,525,683
Arthur D. Little	$5,483,924
Carnegie Mellon Univ.	$5,384,127
Johns Hopkins University	$5,292,000
GTE Corp.	$5,284,354
Northrop	$5,207,825
Motorola	$4,990,266
State University of N. Y.	$4,975,682
Physics International	$4,900,101
Titan Systems Inc.	$4,856,389
DOE Brookhaven Nat'l. Lab	$4,842,734
Naval Sea Systems Command	$4,687,000
Time and Space Processing	$4,648,841
Auburn University	$4,566,080
Army White Sands M. R.	$4,540,000
Arvin Industries Inc.	$4,426,423
Defense Nuclear Agency	$4,002,000
Texas Tech University	$3,965,055
Planning Research Corp.	$3,906,849
Penn State University	$3,805,638
New York Polytechnic	$3,800,000
S-Cubed	$3,798,000
Physical Dynamics	$3,776,002
Thermacore	$3,707,110
Analytic Decision	$3,701,000
Optical Sciences	$3,690,896
Eastman Kodak	$3,550,920
Naval Surface Weapons Ctr.	$3,532,700
IIT Research Institute	$3,348,564
Physical Sciences	$3,339,573
Coleman Research	$3,269,885
AF Space Division	$3,261,000
MIT	$3,117,000
Fenix & Scisson	$3,050,000
Alphatech Inc.	$2,951,269
Eng. & Econ. Research	$2,770,955
Univ. of Arizona	$2,643,633
Cubic	$2,608,028
Washington Patrol Service	$2,546,202
Army Letterman Inst.	$2,500,000
Uniformed Services Univ.	$2,500,000
Polaris	$2,498,175

Lawrence Livermore National Laboratories is the top SDI contract winner, with about $725 million in awards since 1983, according to statistics filed by the Federation of American Scientists (FAS). In listing Livermore at the top, FAS estimated the lab will receive $500 million for its contribution to a free electron laser that will be built at White Sands, New Mexico, over the next three years. A free electron laser is a shortwave laser that tunes its wavelength by passing its beam through "wiggler magnets."

Livermore also holds a $210-million contract for the Excaliber program, an X-ray laser driven by a nuclear explosion.

General Motors/Hughes Aircraft is the number two contractor with $580 million in contracts. Hughes holds large subcontracts on several SDI programs, including airborne optical sensor, exoatmospheric reentry vehicle interception system and high endoatmospheric defense interceptor.

Lockheed, with $520 million in contracts, is in third place. Lockheed's big SDI contract is the exoatmospheric reentry vehicle interception system (ERIS), a ground-based optically guided rocket for midcourse nonnuclear hit-to-kill reentry vehicle interception.

TRW, the main contractor on the Alpha laser program, holds $354 million in SDI contracts awarded since 1983. Alpha is a chemical laser technology development project that would have space-based laser applications. Next on the list is McDonnell Douglas, which holds $350 million in SDI awards. McDonnell Douglas' big project is the high endoatmospheric defense interceptor, a ground-based nonnuclear kill interceptor for terminal defense.

Boeing Aerospace, the sixth largest SDI contract winner, is developing the airborne optical sensor, a missile tracking system mounted on a modified Boeing 767, which uses laser and infrared sensors.

All of the above organizations, with the exception of Boeing, have major installations in California. Companies and universities in California have received more than 54 percent of SDI contracts over the last three years, according to data compiled by the FAS. In fact, more than 93 percent of SDI contract funds have been spent in 10 states: California, 54.4 percent; New Mexico, 8.5 percent; Massachusetts, 7.9 percent; Alabama, 7.5 percent; Washington, 6.4 percent; Texas, 2.7 percent; Virginia, 1.9 percent; New York, 1.6 per-

Naval Ocean Systems Ctr.	$2,390,000	Ralph M. Parsons Co.	$1,298,025	AF Holloman AFB	$970,000	Naval Weapons Support Ctr.	$600,000
Mayo Foundation	$2,370,000	Varian Associates	$1,295,218	Betac	$945,616	Infotec	$598,639
Applied Research Inc.	$2,314,609	Acel Inc.	$1,244,240	Optical Coating Lab Inc.	$941,209	Univ. of New Mexico	$594,875
Analytic Services	$2,290,000	Optimization Technology	$1,242,896	Presearch	$926,636	Mandex	$588,800
Fiber Materials Inc.	$2,232,525	Univ. of Massachusetts	$1,239,864	Austin Research	$925,395	CVD Inc.	$572,415
Computer Science Appl.	$2,214,600	AF Materials Lab	$1,222,000	National Bureau of Stds.	$924,000	Creative Arts Studio	$567,093
Ceradyne	$2,156,725	Advanced Info. & Decis.	$1,205,942	Space Power Inc.	$905,569	Integrated Systems Inc.	$556,589
California Inst. of Tech.	$1,963,911	Univ. of Utah	$1,200,000	Univ. of Maryland	$880,862	Spectron Development Labs	$552,653
Univ. of Alabama	$1,941,811	Baylor University	$1,200,000	California State Univ.	$866,000	Texas A&M University	$550,000
S-Systems	$1,937,000	Creare Inc.	$1,128,745	Space Vector	$842,088	Univ. of Michigan	$547,308
Bedford Research	$1,924,996	AF Arnold Eng. Dev. Ctr.	$1,127,000	La Jolla Institute	$830,603	Contraves Goerz Corp.	$538,000
Orlando Technology	$1,922,922	Rand	$1,120,548	Science Research	$816,021	Photometrics	$527,867
Advanced Research & Appls.	$1,894,000	Univ. of S. Calif.	$1,116,640	Sci Tec Inc.	$815,859	AF Avionics Laboratory	$500,000
Army Kwajalein Missile Rg.	$1,894,000	Aeronautical Research	$1,100,000	Dese Research and Eng.	$813,758	AF Technical Appl'ns Ctr.	$500,000
Army Materials Tech. Lab.	$1,850,000	Brown University	$1,100,000	AF Armamemt Tech. Lab.	$800,000	Army Armament R&D Command	$500,000
Spectra Tech.	$1,829,448	Colorado School of Mines	$1,100,000	DOE Lawrence Berkeley NL	$800,000	Army Finance Center	$500,000
Int'l. Software Sys.	$1,785,383	Drexel University	$1,100,000	AF Western Space/Mssl. Ctr.	$778,000	Defense Elect. Supply Ctr	$500,000
Central Intelligence Agcy.	$1,725,000	Rensselaer Polytechnic	$1,100,000	Pacifica Technology	$764,000	Naval Air Test Center	$500,000
IAP Research	$1,670,000	Ultrasystems Inc.	$1,100,000	Univ. of Washington	$747,821	Toyon Research	$494,357
Photon Research	$1,664,001	Univ. of Florida	$1,091,413	Univ. of Illinois	$747,441	AF Rocket Prop. Lab.	$490,000
Sanders Inc.	$1,640,991	Directed Technologies	$1,068,526	Computer Corp. of America	$745,246	Tektronix Inc.	$487,000
Jaycor	$1,633,481	Purdue University	$1,062,996	Visidyne	$727,000	Scientific Systems	$476,233
Ball Corp.	$1,624,033	Geo-Centers Inc.	$1,061,764	Dept. of Energy	$690,000	Microwave Associates	$474,991
Aptek	$1,575,463	Environmental Res. Inst.	$1,052,371	Engineering Analysis Inc.	$673,594	Foster-Miller Inc.	$469,471
Syracuse Research Corp.	$1,513,920	Auburn Research	$1,041,662	AF Eglin AFB	$670,000	Automated Data Mgt.	$467,220
MITRE Corp.	$1,492,000	Technology International	$1,038,753	Harris Corp.	$668,000	Par Technology	$454,860
Electro-Magnetic Appls.	$1,490,793	Princeton University	$1,037,000	Univ. of S. Florida	$650,498	New York Inst. of Tech.	$447,508
EML Research	$1,479,625	Syracuse University	$1,032,861	Systems Integration	$640,217	Army BMD Systems Command	$439,000
DOE Oak Ridge Nat'l. Lab.	$1,400,000	Dynamic Enterprises	$1,018,597	Ares Inc.	$635,666	Macula	$432,273
PDI Berkeley	$1,386,000	Asst. Director Liaison	$1,000,000	MEI Associates	$613,172	John Cockerham Assoc.	$412,475
Northwestern Univ.	$1,349,000	Datatape Inc.	$995,076	Dynamics Research	$612,000	Optimetrics	$412,089
Rockcor Inc.	$1,314,966	Univ. of Wisconsin	$982,755	AF Flight Dynamics Lab	$610,000	Univ. of Tennessee	$403,352
Army Harry Diamond Labs.	$1,300,000	Anamet Labs	$980,000	(Unknown)	$609,000		

Continued on next page

cent; Colorado, 1.3 percent, and Maryland, 1.1 percent.

The best cities for a company to be located in to increase its odds of holding SDI awards are Los Angeles, the San Francisco Bay Area, Albuquerque, Boston and Huntsville, Alabama, according to FAS statistics. FAS has been compiling statistics on SDI contracting since last summer and plans to publish a comprehensive report soon.

SDI money is spent on both research and technology demonstrations in several advanced areas that have space and ground applications. Ground-based lasers and kinetic energy weapons, which could be used in systems that would shoot down incoming ballistic missiles, are heavily funded. Laser and particle beam funding, included in the directed energy weapons program element, grew from $378 million in Fiscal 1985 to $1.615 billion two years later. Kinetic energy weapons, which include electromagnetic railguns and other systems that would knock down missiles by firing small, high-speed projectiles at the attacking rockets, also has an expanding budget. In Fiscal 1985, kinetic energy weapons received $256 million. The request for Fiscal 1987 had grown to $1.002 billion.

Sensors and surveillance systems would provide notice of the launch of enemy missiles and allow the attacking rockets to be tracked in the boost phase, in space and during reentry into the atmosphere. The surveillance program includes technologies to allow a weapon to discriminate between an armed reentry vehicle and decoys. The surveillance program, with a budget that grew from $546 million in Fiscal 1985 to $1.262 billion in Fiscal 1987, includes research in radar technology, signal processing, lasers and infrared sensors.

Battle management and command, control and communications (C^3) was funded at $100 million in Fiscal 1985, and has grown to $462 million in Fiscal 1987. Much of the work in this area is focused on the highly sophisticated computer software necessary to run a strategic defense system, if one is deployed.

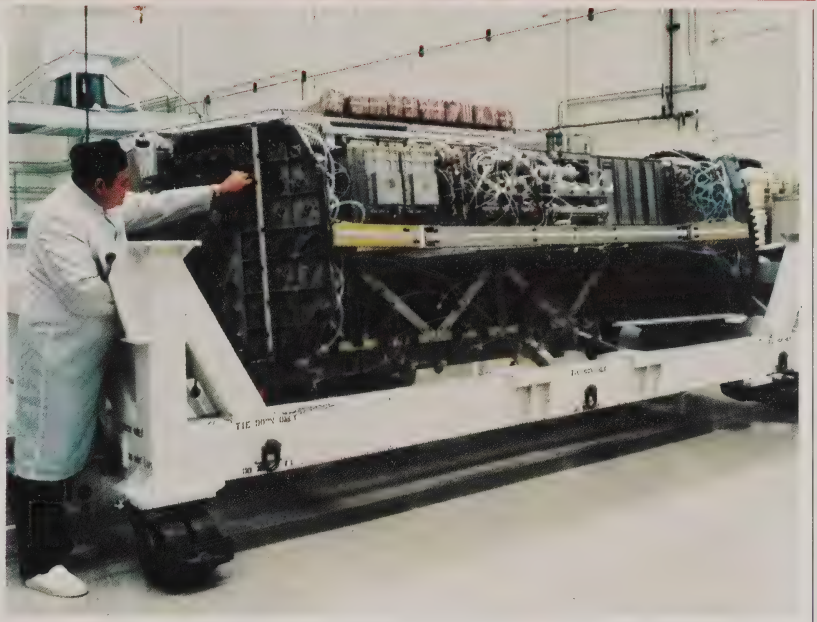
In the survivability and lethality area, the SDI organization spent $108 million in Fiscal 1985 and has requested $454 million for Fiscal 1987. These funds will be spent on technologies that would allow a strategic defense system in space to be protected from attack. Methods of protection include shielding and hardening against lasers or radiation. ●

RECIPIENT	1983-86 CONTRACTS							
SSG Inc.	$402,938	Impar Inc.	$249,993	Ann Arbor Nuclear	$122,857	Orincon	$66,968
Sohar Inc.	$402,478	Naval Weapons Center	$239,000	Energy Resources Group	$122,857	Vanderbilt Univ.	$65,000
Carl Zeiss	$400,216	Effects Technology	$233,000	Rasor Assoc.	$122,857	Sonicraft	$59,048
Small Bus. High Tech Inst.	$400,000	SCEEE Inc. Ed. Mgt. Office	$232,448	MJR Inc.	$122,213	Aerospace Corp.	$55,000
Control Dynamics	$398,268	Boston College	$228,000	Univ. of Oklahoma	$119,922	AF Space Tech. Center	$55,000
Pulse Sciences	$397,379	DOE Pacific Area Sppt. Off.	$215,000	Berner, Lamphier, & Assoc.	$117,151	Naval Post Grad	$55,000
H.H. Aerospace	$396,449	Brigham Young Univ.	$214,620	Vanguard Research Inc.	$117,000	Colorado State Univ.	$50,000
Harold Rosenbaum	$396,000	Xerad	$205,000	Schlumberger	$115,000	Leading Technologies	$50,000
Microwave Monolithics	$394,580	Army Missile Intell. Agcy.	$200,000	Mountain Valley Energy	$114,267	Material Concepts	$50,000
Plasma Research	$393,000	General Electric (UK)	$200,000	Xerox	$112,727	Potomac Digital	$50,000
Helix Technology Corp.	$385,000	DOE Albuquerque Ops.	$200,000	Alabama A&M	$110,000	Atmospheric Science Lab.	$50,000
Yale University	$375,000	Patel Enterprises	$199,925	Univ. of Kansas	$110,000	Adaptive Sensors Inc.	$49,956
Fermionics Corp.	$373,789	Optel	$199,511	Dept. of the Interior	$108,000	Schwartz Electro-Optics	$49,895
Univ. of Denver	$371,716	Ectron Corp.	$199,117	Tinsley Labs	$108,000	Cyberdynamic Inc.	$49,615
Research Support Instrum.	$350,545	Xontech	$199,000	FMC	$105,986	General Systems Grp.	$49,615
Army Research Office	$350,000	Science and Eng. Assoc.	$197,215	Artec Associates	$100,000	Adaptive Technology	$49,000
Naval Intell. Support Ctr.	$350,000	Analytic Sciences	$192,700	Kansas State University	$100,000	Ultramet	$47,645
Aerodyne Research	$336,421	White Scientific	$192,440	Nat'l. Ocean & Atmo. Ad.	$100,000	Marquardt	$46,263
3-C System	$335,524	CSA Eng. Inc.	$187,124	Technical Research Assoc.	$100,000	John Brown Associates	$45,325
Dynalectron	$331,000	Triad	$184,009	Pacific Missile Test Ctr.	$100,000	AF Office of Sci. Res.	$45,000
Polytechnic Inst. of N.Y.	$325,240	New York University	$179,500	Comptek Corp.	$99,468	Systems & Appl'd. Sciences	$44,403
Pacific Sierra Research	$323,451	Electro-Optek	$175,515	Pacific Applied Research	$99,407	Tulane University	$41,320
AF Rome Air Dev. Ctr.	$320,000	General Services Admin.	$172,000	Tracor	$98,000	Univ. of Nevada	$40,700
Radowski Associates	$308,859	Univ. of Iowa	$161,139	Army Armament Command	$94,000	Destiny Plus Two	$35,189
EOS Technologies	$307,928	Lehigh University	$160,000	Radiation Research	$92,984	Prime Source Associates	$35,189
Talandic Research	$306,856	Rohm and Haas	$158,000	Strategy Corp.	$88,222	Univ. of Wyoming	$34,500
Science and Tech. Assoc.	$301,000	DCS Corp.	$154,818	Lambda Physik	$87,200	Systems Control	$28,120
Technical Assistance Int.	$300,177	MMR Tech.	$152,000	Applied Research Assoc.	$85,000	Astrophysics Res. Corp.	$28,000
Pennwalt Corp.	$300,000	Spire Corp.	$150,000	Hyatt Regency	$84,900	AF Logistics Command	$23,000
Software Productivity	$295,000	Southwest Research Inst.	$149,000	Computer Code Consultants	$84,598	International Tech. Corp.	$20,000
Surface Optics Corp.	$287,745	Friel	$148,954	Information Sys. Network	$81,667	Space & Naval Warfare Com.	$20,000
Kent State University	$275,869	Electronic Decisions	$145,781	Harvard University	$80,000	Information Sciences	$15,000
ETA Corp.	$273,601	Ferranti	$142,500	Montana State	$79,982	AF 5010th Combat Sppt. Grp.	$10,000
AF Foreign Technology Div.	$270,000	Heriot-Watt University	$142,500	Great Lake Science	$77,119	M&W Microfilm	$10,000
Univ. of Pittsburgh	$264,830	Analytical Systems	$141,000	J.H. Wiggins	$73,245	Mosler Gov't. Sales	$5,587
B-K Dynamics	$258,000	Fairchild Space Co.	$138,836	Astron Research	$72,705	Microcoatings	$4,440
Technology Service Corp.	$257,000	Advanced Kinetics	$136,410	AF Alaskan Air Command	$70,000	IRT Corp.	$2,000
Measurement Concept Corp.	$253,544	Army Laboratory Command	$131,000	USAF	$70,000	Business Machines of Am.	$664
Geonautics	$252,800	Southern Research Inst.	$129,543	Pinnacle Research	$67,555	Ebsco Subscription Svce.	$427
New Mexico Inst. of Mining	$249,995	Old Dominion Univ.	$129,440	K-Tech Corp.	$67,000	Huntsville Radio	$290

Source: Federation of American Scientists

U. S. LAUNCH CAPABILITY HAS BEEN CUT SHARPLY, INEVITABLY LEADING TO PROGRAM DELAYS

NASA's actions over the next five years will determine whether the U. S. can accomplish its commercial goals in space



McDonnell Douglas
Astronautics electrophoresis production prototype unit, shown at McDonnell Douglas' St. Louis facility, has been mothballed until the space shuttle resumes flights. It was to have flown in July, 1986, for the first time.

Washington

Astrotech, 3M and McDonnell Douglas, three companies in the forefront of the commercial space industry, will be seriously set back by the grounding of the shuttle following the Mission 51-L accident in January. Those firms had commercial space operations planned for 1986 that were totally dependent on the shuttle flying.

Other commercial space ventures in more embryonic stages of development may escape damage unless the shuttle is grounded for several years and subsequent flight rates are drastically reduced. While it appears that space commerce won't be permanently damaged by the shuttle hiatus, a senior National Aeronautics and Space Administration commercial space official warned that if the shuttle is again grounded in the 1990s when space commerce has matured, the impact on the young industry could be fatal.

NASA's actions over the next five years will determine whether the United States can accomplish commercial space goals set out before the shuttle accident.

One commercial space analyst, Chris Roberts, director of venture financing, Center for Space Policy, Inc., said NASA policy on use of the shuttle and other assets could prevent the U. S. from falling behind in commercial space. "But this will require a change in their fleet manifesting philosophy," he said. "They must stop thinking of themselves as a commercial trucking company and return to their roots, go back to being the excellent R&D agency that they were created to be."

The commercial space ventures that will be affected this year by revenue shortfalls or the grounding of experiments include:

- **Astrotech**—Satellite processing operations at Astrotech's Titusville, Florida, facility have come to a halt. "If the shuttle is out of business, we're out of business," Robert Goss, Astrotech Space Operations president, said.

Astrotech's satellite processing subsidiary brought in about $4.8 million in gross revenues in 1985 and had pretax profits of more than $1 million. The shuttle hiatus is expected to severely affect 1986 earnings. "It could be a complete wipeout in 1986 as far as satellite processing goes," Goss said.

Astrotech may be able to earn some interim revenues from storing grounded satellites. The company will try to sign up ELV customers, if any exist, for its facility. Astrotech officials believe that, under a worst case scenario, shuttle communications satellite launches will not re-

RCA Astro Electronics-built communications satellite belonging to American Satellite Co. undergoes prelaunch testing in summer, 1985, at Astrotech Space Operations's Titusville, Florida, satellite processing facility. Launch of ASC-2 has been delayed indefinitely.

sume for two years. They are evaluating whether Astrotech Space Operations can survive that long without work.

■ **3M**—Four experiments were planned over the next year and all will be delayed, according to Christopher Podsiadly, 3M's science research laboratory director. 3M's space experiments are in the basic research phase, so the grounding of 3M's experiments will not mean a stop in production or revenues.

The delayed experiments include: Diffusive Mixing of Organic Solids (DMOS 3); Physical Vapor Transport of Organic Solids (PVTOS 2/3); the first Polymer Morphology (PM 1) test, a joint experiment with General Motors to study the structure of synthetic polymers.

Negotiations for a 10-year agreement with NASA for shuttle and space station experiments were slowed after the accident. 3M has asked for seventy-two flight opportunities, but the loss of an orbiter has caused NASA officials to reexamine their ability and willingness to commit that much shuttle capacity to one company, a NASA official said.

3M and NASA have agreed on an allocation of flight opportunities based on the number of orbiters available each year. Signing of the 10 year agreement was being held up by unresolved government liability policy issues regarding point endeavor agreements.

The 3M commitment to space research remains strong, said Podsiadly. Two weeks after the shuttle accident, both the corporate operating committee and the board of directors gave the go-ahead to proceed with the space research program "as if nothing had happened," he said.

NASA has not informed 3M when it can expect to resume space experimentation. "The main thing I need is some kind of timetable," Podsiadly said. "It's tremendously helpful to industrial planning."

■ **McDonnell Douglas**—McDonnell Douglas' pharmaceutical processing in space will stop for at least a year. McDonnell Douglas was much closer than 3M to moving into space production of a marketable product, so the lack of flight opportunities probably will do more damage.

Flights of McDonnell Douglas' new electrophoresis prototype production plant, which moves operations from the shuttle middeck to the cargo bay, were planned for July, 1986, and February, 1987. One of those missions may fly in the August-December, 1987, time frame.

James Rose, McDonnell Douglas director of electrophoresis operations in space, said the company will try to minimize the impact on the program and the first product, erythropoietin, by transferring some activities to ground electrophoresis units. He said early commercialization of erythropoietin can be accomplished with ground processing. "If we had to depend entirely on space processing for early commercialization, we would have been dead in the water," Rose said. "We have been fairly successful in getting material sufficiently purified with ground electrophoresis. We can continue developing the product using ground-based processing until space flights resume."

McDonnell Douglas is searching for a new pharmaceutical partner to test and market erythropoietin, since 3M Corp.'s Riker Labs pulled out of the venture. Significant advances have been made in the ground electrophoresis process, which should make the project more attractive to prospective partners, Rose said. Ground electrophoresis will permit McDonnell Douglas to move at "a pace that will allow us to catch up with the competition," Rose said. Genetic engineering firms are competing for the

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erythropoietin market with an alternative process that is entirely ground based. McDonnell Douglas still intends to use space processing for large-scale production of erythropoietin, but that is several years off, he said.

McDonnell Douglas has mothballed the production plant and reassigned about 30 engineers until a new launch date is known. "We can't afford to keep a large crew on standby," Rose said.

McDonnell Douglas hoped to see return on its investment in electrophoresis in 1988. Rose said it is possible that schedule can be maintained, despite the disruption in space flights.

Both McDonnell Douglas and 3M have committed substantial resources, including money and top company researchers, to their space projects. It is not clear how long those corporate commitments will be maintained if researchers are restricted to ground experimentation for more than one year. If these companies must suspend space experimentation for several years, the corporate commitment to space research is likely to weaken considerably.

Space bioprocessing research with commercial applications also will be set back. The University City Science Center (UCSC) of Philadelphia was planning to launch a Getaway Special canister carrying protein crystallization and membrane casting experiments on a June shuttle flight. "The experiments will sit until [the shuttle] can fly again," William Claybaugh, UCSC vice president-space division, said. "We have no access to low gravity, except for the Russians, and they aren't offering it commercially yet." But much can be done on the ground to refine the experiments while waiting for the shuttle to get back into space, said Claybaugh.

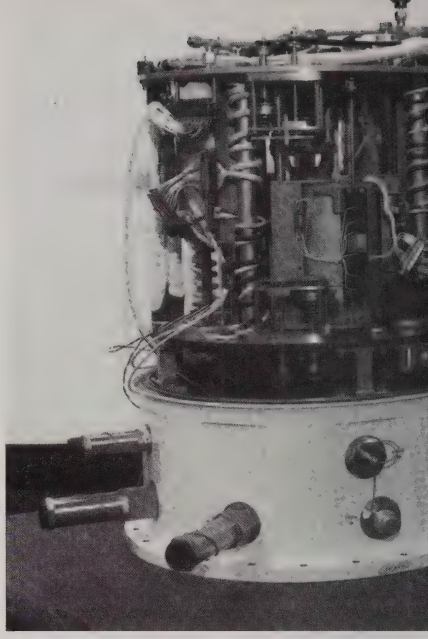
The shuttle hiatus is expected to severely affect 1986 earnings. An Astrotech official said 'It could be a complete wipeout as far as satellite processing goes'

Another protein crystallization experiment, sponsored by NASA and the University of Alabama, Birmingham, was planned for launch in late 1986. It also will be delayed. The top commercial space official at NASA, Isaac T. Gillam, assistant administrator for commercial programs, said he does not expect either his programs or private sector holders of joint endeavor agreements to suffer much from shuttle delays. Most commercial payloads are relatively small, can fly in the shuttle middeck and are considered secondary to larger payload bay cargo. "We don't have a long line of payloads waiting," Gillam said.

The Office of Commercial Programs has 10 joint endeavor agreements and two modified launch services agreements that commit the agency to commercial payload launches. Six more JEAs are being negotiated and two of those will be signed soon.

Gillam said NASA has not determined the priority of the commercial payloads or decided which will be offered the first flight opportunities when shuttle launches resume. Nor does the Office of Commercial Programs have any assurance that its customers will be allocated space on early missions, but "we have to assume there'll be empty lockers" that can accommodate commercial experiments, he said.

After the accident, NASA established an internal task force of senior headquarters managers to develop a recovery plan. The task force



was to evaluate the implication of the accident on NASA's future. Decisions affecting the future of commercial space programs and projects were put on hold pending completion of the agency-wide recovery plan.

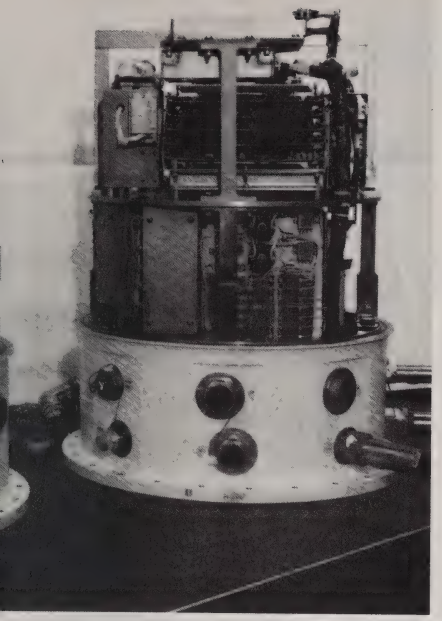
While communications satellites scheduled for shuttle launches can be shifted to expendable launch vehicles (ELVs), other commercial ventures are locked into using the shuttle. Companies involved in materials processing or in-orbit servicing are vulnerable to shuttle schedule problems because their business plans depend on two-way transport to low Earth orbit. For them, there's no substitute for the shuttle.

Before the Jan. 28 accident that destroyed Challenger, NASA was planning twenty-four shuttle flights a year beginning in 1989. The reduced orbiter fleet and increased attention to flight safety in the aftermath of the accident will result in a much lower annual flight rate, engendering competition among commercial payloads for early manifest slots when shuttle operations resume.

The long-term effect of the reduced orbiter fleet and lengthy shuttle grounding on commercial space have not yet become apparent. Several commercial space companies expect little or no change to their plans, officials said.

The Industrial Space Facility (ISF) planned by Space Industries for the 1990s will not be affected by the accident, said Joseph Allen, Space Industries executive vice president. Construction of the ISF, a free-flying module for lease to companies and researchers who want a microgravity environment, will not start until 1988. ISF, which will cost several hundred million dollars to develop, will be deployed from the shuttle for unmanned operations. ISF will be serviced by shuttle astronauts, who will be able to work inside the module in their shirtsleeves for limited periods of time.

ISF is targeted for a late 1989 or early 1990



launch. "The question for NASA is 'can you accommodate the contract with Space Industries then?' " said Allen. Space Industries signed a modified launch services agreement with NASA last year that allows the company to defer launch payments until two years after launch, when it's earning revenues. Space Industries timetable also could suffer if ISF users, who still have much development to do before they're ready to use the module, are delayed by the shuttle grounding. Allen said, "Prior to committing large sums of money, we will have clients ready to use the ISF. We will time our plan to those clients."

Another company planning a microgravity module, Spacehab, Inc., also says its plans will not be changed by shuttle delays. "There is a good chance Spacehab will fly on schedule or at most be delayed by a few months," Robert Citron, Spacehab president, said. The first Spacehab launch date continues to be mid-1988, although Citron said he is not certain NASA can meet that. Spacehab is a cylindrical pressurized module designed to fly in the shuttle cargo bay attached to the crew compartment. It will expand the volume of crew compartment area, allowing more experiments, equipment or other cargo to be flown inside the pressurized section of the shuttle, where the crew can work with it. Spacehab will lease all or part of a module to commercial or government users.

Citron said demand for Spacehab capability has skyrocketed due to the growing backlog of shuttle middeck payloads. But Spacehab has yet to identify its first customer. "The demand for man-tended workspace has increased. We believe that will be a high priority item" when a new manifest is issued, he said. Spacehab may leapfrog other commercial payloads on the shuttle manifest because the military and Strategic Defense Initiative, which have the highest priority, will use the module.

Citron predicted that although the shuttle accident will have a major impact on commercial space investment, Spacehab will escape financial repercussions because its investment commitments are firmly in place. He said the company was fortunate to raise $1 million one month before the accident because commercial space investors since have adopted a reluctant "wait-and-see" attitude.

Orbital Sciences (OSC), a commercial upper stage company that just signed NASA as its first customer, doesn't expect the launch of its first booster in 1990 to be delayed. In March, NASA ordered a transfer orbit stage (TOS) for the Mars Observer mission. Scott Webster, OSC vice president-marketing, said the shuttle accident hurt OSC in its competition with Boeing for an upper stage contract to launch Tracking and Data Relay Satellites. NASA lost the second TDRS in the shuttle explosion, and Webster said the agency could not deal with risks associated with getting TOS, a brand new system, ready to launch TDRS-E and TDRS-F. Boeing's Inertial Upper Stage, the ultimate winner of the TDRS competition, has a proven flight record and is perceived to have less schedule risk.

Because commercial satellites may be forced off the shuttle and on to ELVs, OSC may alter its TOS marketing strategy. Webster said OSC has restarted talks with British Aerospace that would allow use of the Spelda dual-payload adaptor, a piece of hardware built by British Aerospace to mate two satellites to the Ariane 4.

OSC also may try to convince commercial satellite owners to launch using TOS on top of a Titan. Martin Marietta manufactures both Titan and TOS, and the two are compatible.

Materials processing in space (MPS) companies, none of which are earning revenues today, will be seriously set back if they cannot find guaranteed transportation to low Earth orbit and back.

"Delays in shuttle launching will have an immediate and serious impact on the development of the commercial MPS industry," said an analysis by Center for Space Policy, Inc. "Large aerospace and materials firms remain intent on continuing their space-production plans, but they will slow funding for research until they can be assured of access. Small entrepreneurial MPS firms may lose investor support as a result of delays in reaching operational status." But entrepreneurs said they weren't aware of any such repercussions.

Microgravity Research Associates, which plans to manufacture gallium arsenide in an isothermal furnace on the shuttle, expects no impact from the delay, Robert Pace, vice president, said. The Microgravity Research payload will be ready for its first flight in spring 1988.

It will be mounted in the shuttle cargo bay on the Materials Science Lab, which Pace said will "fly frequently in that time frame."

Boeing, which plans a materials processing furnace for the shuttle, expects some delay in the first launch date. But the Boeing furnace already had slipped by a year because negotia-

NASA's automatic directional solidification furnace would have flown on the shuttle in November on a Materials Science Lab mission. The furnace will process magnesium bismuth sample material on its first flight, the date of which is uncertain.

3M has asked for 72 flight opportunities, but the loss of an orbiter has NASA reexamining its ability to commit that much capacity to just one company

tions with NASA took longer than expected, a Boeing official said.

NASA's microgravity science program planned three cargo bay and six to ten middeck experiments for 1986 that will be delayed. Kathryn Schmoll, NASA deputy director for management in the microgravity science division, said the division was evaluating how to recover from the shuttle hiatus. "Much of our flight equipment is modified sounding rocket equipment," she said. "We hope to use the hiatus in shuttle flights to accelerate new equipment and improve the old."

Three Materials Science Lab experiments were set to fly in November and will be delayed. They are: the automatic directional solidification furnace, which was to produce a magnesium bismuth sample material for a principal investigator from Grumman; electromagnetic levitator, which would use a containerless processing technique on nickel-tin alloy; and three-axis acoustic levitator, an experiment with applications in fluid dynamics and glass refining that involved manipulating drops in an acoustic field.

The list of middeck payloads that were ready for 1986 flights included an isoelectric focusing unit, which involves another method of separation to accomplish a task similar to electrophoresis; a middeck version of the automatic directional solidification furnace; the monodisperse latex reactor, which manufactures the tiny latex spheres that are being sold by the National Bureau of Standards; a phase partitioning experiment, which is a handheld device that investigates the separation of liquids of different viscosity in microgravity.

Schmoll said no decisions had been made on which payloads will fly first when shuttle missions resume.

Commercial ventures will have increasing difficulty in obtaining insurance for new ventures in the wake of the accident because underwriters' perception of the extreme risks of space-related businesses has increased.

"We can no longer sell underwriters on the idea that the shuttle phase is safe," Brian Stockwell, president of Corroon & Black Inspace, a space insurance brokerage, said. "The underwriters' confidence in the industry depends on how the fix [to the shuttle] appears." With the shuttle down, a major source of revenue for the space insurance industry will be blocked. Stockwell predicted 1986-87 will be bad years for insurers, who just experienced two disastrous years when more than $600 million worth of satellite claims were paid.

Negative publicity directed at NASA since the accident will make an impression on underwriters, he said. In January, Inspace was in the midst of arranging a deal with underwriters to provide special coverage for shuttle customers during the launch-to-low-Earth-orbit phase. The deal has been put on hold because of the accident, Stockwell said.

Proposals to privately finance another orbiter will benefit from the urgent need for additional launch capacity in the U.S.

NASA is expected to issue a request for proposals soon for a privately financed orbiter from General Space Corp., a subsidiary of Astrotech, and other interested companies, according to Gillam. General Space and three other companies—Captronics Manufacturing, Inc., Dallas; Independent Business Consultants, Stoughton, Wisconsin, and Batten Heads, Inc., Romulus, Michigan—responded to NASA's request for expressions of interest in a privately owned orbiter.

General Space has proposed that it finance construction of the orbiter in exchange for a 15-year lease from NASA, which would retain management, launch, operation and maintenance responsibility for the vehicle. General Space also is asking that it become marketing agent for the entire shuttle fleet to the commercial sector. In addition to the annual lease payments, General Space would share in revenues from shuttle launch contracts on an incentive basis.

A possible sticking point to the proposal is General Space's demand that the government assume the risk of loss or damage to the orbiter. Insuring a privately owned orbiter is expected to be difficult.

NASA has considered proposals for privately financed orbiters twice in the past, but rejected both on the grounds that they were not a good deal for the taxpayer.

General Space's management team is packed with aerospace heavyweights, including several officials with a long history of association with NASA, which may strengthen its chances of winning government approval. Board members include former Johnson Space Center Director Gerald Griffin and former astronaut Eugene Cernan. NASA administrator James Fletcher recently resigned his position on the board.

While the communications satellite industry hasn't yet experienced a transponder shortage from the grounding of satellites that were to be launched on the shuttle, some satellite owners are scrambling to find alternative launch vehicles. Some shuttle users, notably American Satellite and the British Defense Ministry, are expected to stay on the shuttle because of the great expense and inconvenience of moving to expendables. But others, for example GTE Spacenet, India and Indonesia, were shopping for replacement ELVs that could get them into orbit earlier.

Satellite owners will be hit with higher launch costs because the shuttle, which often leads the market in pricing, will be out of the competition. Arianespace announced a 30 percent price increase this spring, although that was attributed to the fluctuation of the value of the dollar versus the French franc, not to the withdrawal of the shuttle from the launch market. Despite rising prices, Arianespace planned to announce in June a new manifest that includes some customers who were booked on the shuttle before the accident.

U. S. companies offering alternatives to the shuttle may benefit from the accident. U. S. expendable launchers—Delta and Atlas-Centaur—have not been able to compete successfully with the shuttle and the European Ariane in the past for a variety of reasons, primarily price. Martin Marietta's Titan, which is being produced for the Air Force, may get another shot at the commercial market. ●

A smaller orbiter fleet and more attention to flight safety will result in a much lower annual flight rate, engendering competition for early manifest launch slots

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WITH AMERICAN LAUNCH SYSTEMS GROUNDED, ARIANE IS MOVING TO FILL THE GAP

Europe's Ariane inaugurated a new launch facility in French Guiana, ELA-2, with a March mission that placed U. S. and Brazilian satellites in orbit

Kourou, French Guiana

The personnel in the Ariane control room here were all smiles Mar. 28 when the long-awaited words "separation of Brasilsat" boomed from the speakers, signaling the successful completion of Ariane mission V17 that placed Brazil's Brasilsat 2 and the U. S. GTE Spacenet's GStar 2 communications satellites into highly accurate geostationary transfer orbits.

Success of the V17 mission provided an important boost to Europe's Ariane program—which has become one of the Western world's key sources of launch services following the series of mishaps with the U. S. space program.

The V17 mission was an important one for Ariane because it marked the initial flight from the new ELA-2 launch facility here, as well as the first Ariane 3 launch since the in-flight destruction of the V15 launcher in September, 1985, due to a third stage propulsion problem.

"These days, every launch assumes key importance because of problems that have plagued space launches recently, but for the Ariane program, V17 was critical because it provided a real-life checkout for ELA-2, as well as demonstrating we have overcome the problems that led to the loss of V15 last year," one Ariane engineer said after the successful mission.

Brasilsat 2 was part of a dual payload carried on Ariane V17. It was mounted in the lower part of Ariane's Sylda, in an egg-shaped composite material structure developed by France's Aerospatiale. Sylda enables each Ariane to launch two medium-sized telecommunications satellites—thereby allowing launch costs to be shared among two satellite customers. GTE Spacenet's GStar 2 was mounted atop the Sylda, and was released first in the deployment sequence, followed by Brasilsat 2.

Before the U. S. shuttle Challenger disaster in January, Ariane already had established itself as a viable competitor in the international launch services marketplace. The destruction of Challenger, however, brought the world's satellite operators to Ariane's door when it became clear the main element of the U. S. space program would be on hold into 1987.

Arianespace—Europe's commercial management/marketing organization for Ariane—moved in to help fill the gap, although the feeling expressed by Arianespace officials is one of sadness over the shuttle disaster rather than satisfaction over the setback suffered by the U. S.

"We never wanted to profit from the misfortunes of others, and the shuttle tragedy in the U. S. was a tragedy for Europe as well—even in the hottest of competitions such a loss is felt by all in the worldwide space community," one program official said.

On the other hand, Arianespace officials do not hesitate to point out that they had warned against the increasing dependence of the world's satellite makers and operators on the U. S. shuttle program without making provisions for a second source of launch services.

"We had suggested many times that major satellite companies consider splitting their payloads on the shuttle and on expendable vehicles such as Ariane, giving them two sources in the event either program suffered a major setback," one French official said.

"We couldn't understand how the top decision-makers could have 'put all their eggs in one basket' without looking at all of the eventualities possible. I think people began believing the shuttle really was a space truck that could be launched every few days, and they overlooked the fact that the shuttle program still had a long way to go before it was totally routine—if you can ever call launching a complex manned spacecraft routine," he said.

As a result of the shuttle problems, the eight remaining Ariane payload slots that had been available through the end of 1988 now are reserved by satellite customers, and the demand is so strong that other clients have asked to be "double booked," giving them the chance to take over a slot in case something opens up. The organization also is reporting a brisk demand for slots beyond 1988 as it begins to lay out its manifest for the rest of the 1980s and into the early 1990s.

Customers who have signed up for the eight remaining slots placed $100,000 nonrefundable reservations for the positions, and Arianespace has been working to complete the reservations as firm orders. The reservations, placed by customers in Japan and elsewhere, had a validity of 30 days while negotiations on formal contracts were being completed.

"We have been swamped with demand, and in addition to the reservations for each of the eight payloads, we've met the requests of some customers asking for a 'right of second refusal,'" Frederic d'Allest, Arianespace chairman and chief executive officer, said.

According to Arianespace projections, there is the need for the launch of 20-25 satellites by expendable vehicles per year in the late 1980s and 1990s, and the company hopes to be launching 10-13 of these payloads per year on an average. This will enable the European launcher program to schedule seven to eight launches per year through 1994.

D'Allest noted the actual share Ariane cap-

Europe's Ariane V17 lifts off from the new ELA-2 launch pad at the Guiana Space Center on a successful mission which orbited communications satellites from the U. S. company GTE Spacenet and Brazil's Brasilsat.

tures in the long term will depend on several factors, including the rate at which the shuttle program recovers, and what new launch competitors will emerge in the coming years. Another factor is the currency exchange rates, which, through the wildly fluctuating rate of the dollar, have affected Arianespace's pricing.

"While Europe's aerospace industry has been fighting to gain a few percent on production costs for Ariane on one hand, the exchange rate has varied about 30 percent in nine months, and no one can tell at what level it will be in four years," d'Allest said.

Arianespace reported booking 11 new payload launch service contracts in 1985 at a combined value of about 2.9 billion French francs (about $414 million at current exchange rates) and increased its capital from 120 million French francs ($17 million) to a new level of 270 million francs.

One U. S. aerospace industry manager said Arianespace's 1985 performance was proof that Ariane had become "a viable competitor even before the shuttle accident transformed Ariane into one of the only real sources of regular launch services in the Western world."

"And even if there are other expendable launcher programs organized in the U. S. as a result of the shuttle disaster, Ariane will have a lead of several years on them and will be able to strengthen its market presence with a more or less captive market," the executive said. "I think too many people outside France underestimated the determination—and the skill—behind the Ariane program. This underestimation, and our own blind reliance on the space shuttle as a 'single source' of launches, have given Ariane a real competitive edge today."

Arianespace, working with Europe's aerospace industry involved in the Ariane program, is taking several steps to increase the launcher's future competitiveness.

This includes introduction this year of the Ariane 4 increased-lift launcher family, which was designed to improve Ariane's payload capability and cost-effectiveness, followed ultimately by the Ariane 5 heavy-lift launcher, which will be able to increase significantly the payload capabilities into geostationary transfer and low Earth orbits, as well giving Europe a manned capability with France's proposed Hermes minispaceplane.

First flight of an Ariane 4 is planned for the second half of 1986, while Ariane 5 is expected to enter service in the mid-1990s.

Ariane's ability to compete has been improved by introduction of the Guiana Space Center's new ELA-2 launch pad, which is one of the most visible signs of the launcher pro-

Ariane 4 launcher growth version will increase Europe's competitiveness in the international launch services market. Shown above and on facing page at Aerospatiale's facility in France is the first stage for the No. 1 Ariane 4 which will be launched later this year. The first stage is longer than on the predecessor Ariane 1/2/3 launcher family.

gram's evolution since the first Ariane was fired from Kourou in 1979.

In contrast to the ELA-1 facility—where each Ariane is assembled and its satellite payload integrated on the launch pad—ELA-2 features separate integration and launch sites. In the new arrangement, an Ariane is assembled on a mobile launch table in ELA-2's large vertical assembly building, then rolled on its table a distance of 1 km. (3,280 ft.) to the launch site.

The separation of assembly and launch zones at ELA-2 allows one Ariane to undergo the satellite integration and final checkout in the launch zone while a second is being built up in the vertical assembly building. This enables one mission per month to be conducted from ELA-2, although the limit is expected to be about 10 per year based on maintenance considerations.

ELA-2 covers 50 acres at the Guiana Space Center. Construction of its facilities took about four years and cost $125 million at 1984 values. The French CNES space agency acted as prime contractor for ELA-2's construction, and the program was cofinanced by France, West Germany, Belgium, Denmark, Great Britain, Spain, Italy and Switzerland.

The Guiana Space Center was established in 1964 by France and is operated under CNES. The ELA-1 and ELA-2 launch sites are considered to be the property of Europe's multinational European Space Agency, but are operated by Arianespace. The satellite payload preparation complex also belongs to ESA, is operated under CNES responsibility, and is rented by Arianespace for its commercial clients.

While ELA-1 is able to handle the basic Ariane 1/2/3 launcher series, ELA-2 will be able to accommodate these vehicles as well as the various Ariane 4 configurations that will be powered by solid or liquid strap-on boosters or a combination of the two.

Other major physical improvements at Guiana Space Center include the new S1B cleanroom facility, a modern building with a cleanroom area 50 meters long and 16 meters wide (164 × 52 ft.), which can handle as many as three satellite payloads simultaneously. The facility has a 10 × 10-meter (33 × 33-ft.) block in the floor that is isolated from vibration to allow the final calibration/checkout of high precision optical systems for Earth observation and weather satellites.

Other changes at Kourou that are less visible but important in Arianespace relations with its customers are improvement in the living environment for its customer satellite checkout teams, which have to spend several weeks in French Guiana before launch. In the case of the V17 launch, the team for Brasilsat 2 was headed by Canada's Spar Aerospace, Ltd., while RCA Astro Electronics had its own team on site for the checkout and integration of the GStar 2, which RCA built for GTE Spacenet.

The time spent at Kourou for the preflight preparations can become long for many of the teams—especially if there are launch delays that extend the time spent there. There are only so many places to visit and things to see in this tropical country, and the fact that airline connections are somewhat limited complicates the ability to move team members between their home locations and Kourou.

"Since many of the satellites launched by Ariane are made by U. S. manufacturers, we needed to provide support for the U. S. personnel who are accustomed to different conditions when they work on a launch. Let's face it, Kourou is not Cocoa Beach; and French Guiana isn't Florida," one Arianespace official said.

"There were some people just plain homesick, and there wasn't enough for them to do in their free time. Entertainment is limited, and language becomes a problem, especially for the simple things as watching television, going to the movies or ordering in a restaurant," the Arianespace official said.

To improve conditions, Arianespace took a number of steps, including working with the local business community to establish American-type grill restaurants and hiring a guide service to conduct escorted tours into the interior of Guiana and down jungle rivers.

Another significant effort was made by

Ariane program personnel to work with Air France on improving airline service to French Guiana, particularly when groups of satellite customer team members are going to or from Kourou during key periods before or after launch. In some cases, additional flights from the U. S. or Europe to Kourou are being added by Air France, while in other cases priority is given by the airline to launch-related personnel over other passengers.

"It became evident early on that we needed to strengthen our support of the satellite teams assigned to Kourou because of the remoteness of Guiana and the cultural differences—especially for the Americans," Patrice Albrecht, Arianespace's manager of the customer services department, said. "One advantage of having a commercial organization like Arianespace in support of the Ariane program is that we were able to respond positively to the needs of customers, and we have been able to improve day-to-day working conditions for them.

"We looked at the big items, such as the airline connections and living conditions, as well as the little things such as producing a booklet in English and French which lists important telephone numbers and services, outlines the restaurants and gives an idea of the leisure activities possible in the region," Albrecht continued.

One supervisor for Spar Aerospace said a number of changes for the better have been instituted between the launch of the company's first satellite on Ariane—Brasilsat 1 in February, 1985, on board Ariane V12—and the Brasilsat 2 mission last March 28.

One area that remains a point of difficulty is lodging—since renting hotel rooms continues as the main source of quarters for the visiting teams. "At the Cape [Canaveral/Kennedy Space Center], we'd rent condominiums, which means you don't have to go out and eat every night," one Spar manager explained.

John Korda, a specialist engineer for Canada's Telesat who was part of the Brasilsat 2 launch team, said living conditions at the main Kourou hotel—Hotel des Roches—brought back memories of early Canadian satellite launches on NASA/McDonnell Douglas Delta vehicles from California's Vandenberg Air Force Base.

"I remember the conditions for our early launches from Vandenberg weren't always fantastic. Lompoc [the nearest main city to Vandenberg] was no garden spot, and our hotels there were not luxurious by any means. And while there still are some improvements to be made at Kourou, I think we sometimes forget things take time, and you don't end up with an operation like Cape Canaveral overnight."

In addition to the steps taken by Arianespace, the producers of satellites carried on Ariane also made adjustments to help improve the conditions for their personnel. One U. S. manufacturer began rotating its technical crews through Kourou and it also sent down a freezer of hot dogs and hamburgers for home-style picnics.

C. J. Wayland, GTE Spacenet Corp. president, which is one of the largest single U. S. clients to have signed with Arianespace for Ariane launch services, remains a satisfied customer even though his Spacenet 3 satellite was one of the payloads destroyed during the unsuccessful Ariane V15 launch last year.

"There's really no question that Arianespace is a very high quality organization, and they've weathered the unfortunate losses they have had," Wayland said. "It's a fact that our business is a risky one, and there are inherent risks that just can't be reduced to zero.

"Arianespace, fortunately, has been cognizant of this from the beginning. They have been able to recover from the setbacks. Arianespace always has been straightforward with us, and they have been accommodating to our needs to the maximum extent possible."

The Guiana Space Center's technical facilities made available for satellite preparation and checkout have received high marks from U. S. and non-U. S. aerospace personnel alike.

"The conditions are every bit as good as Cape Canaveral—maybe even better," one Spar Aerospace manager said. "I give the facilities and the Ariane team a 'first class' rating." ●

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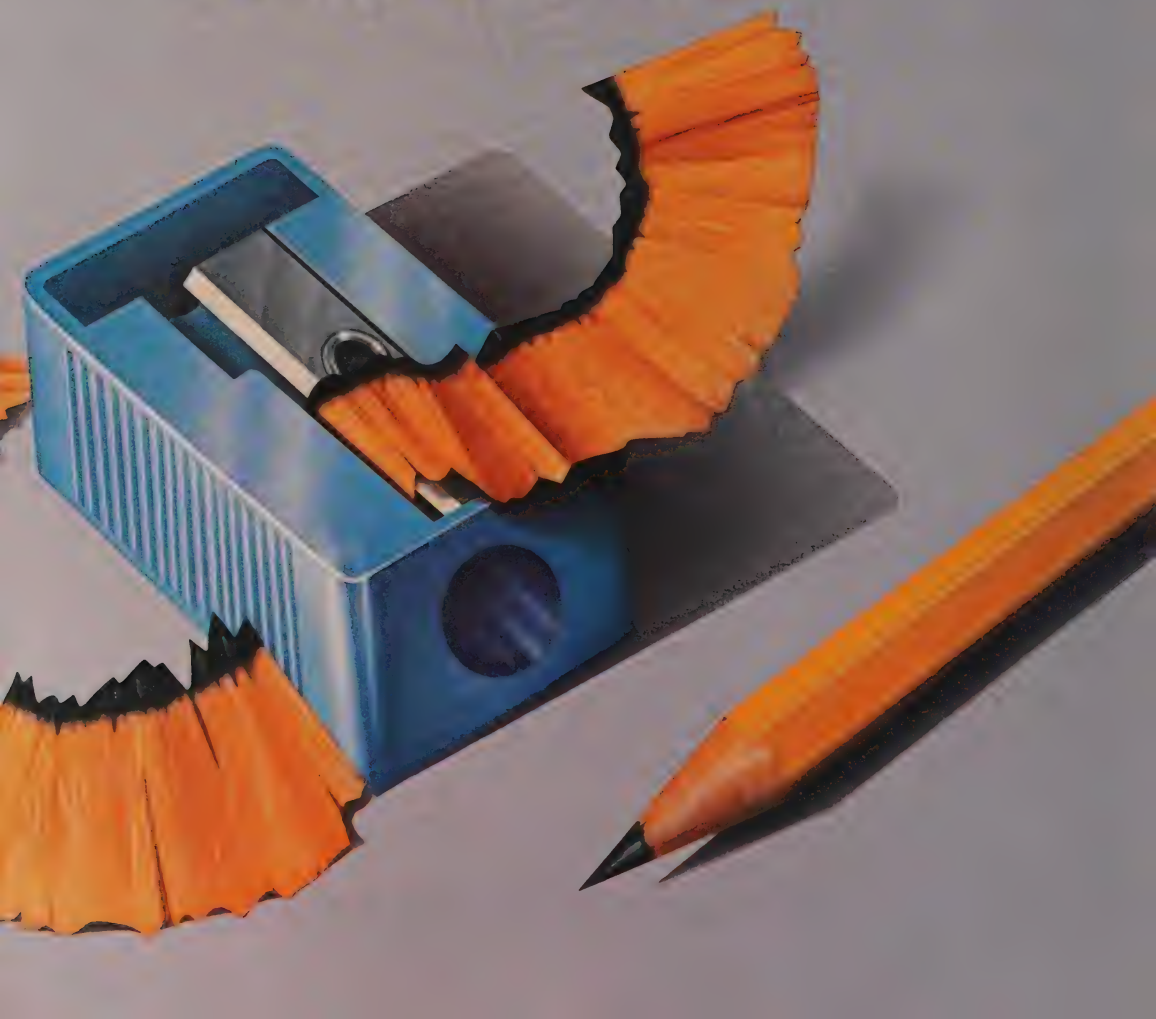

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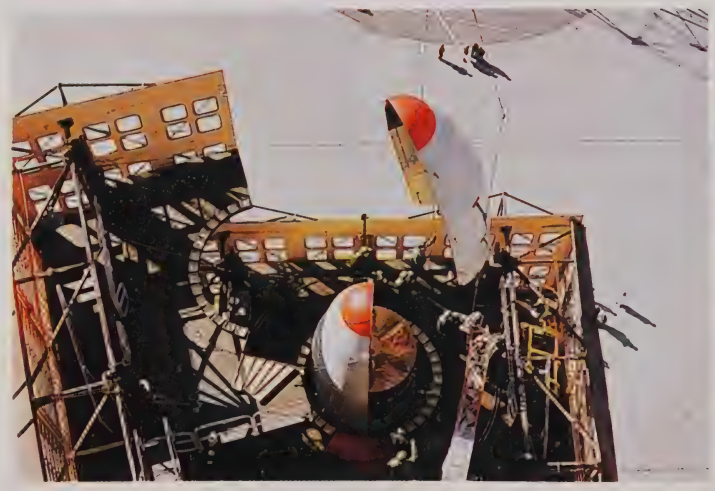
CHINA READIES LONG MARCH BOOSTERS FOR LAUNCH

Chinese booster preparation at the new Xichang launch site includes mounting the satellite on the vehicle (photo at lower left) without the benefit of clean room protection. China's second geosynchronous orbit satellite is open to dust and humidity contamination as the nose shroud of the vehicle is placed around the payload and clamped shut (bottom right). Two Long March 3 boosters (photo at left) are shown in the modern vehicle checkout building at Xichang. The Long March 3 has a third stage powered by liquid oxygen and hydrogen and can place 3,000 lb. in geosynchronous transfer orbit. The Chinese have launched three vehicles with this configuration, including two that were successful and one that was a partial failure when the third stage failed to activate for the second of two planned burns.



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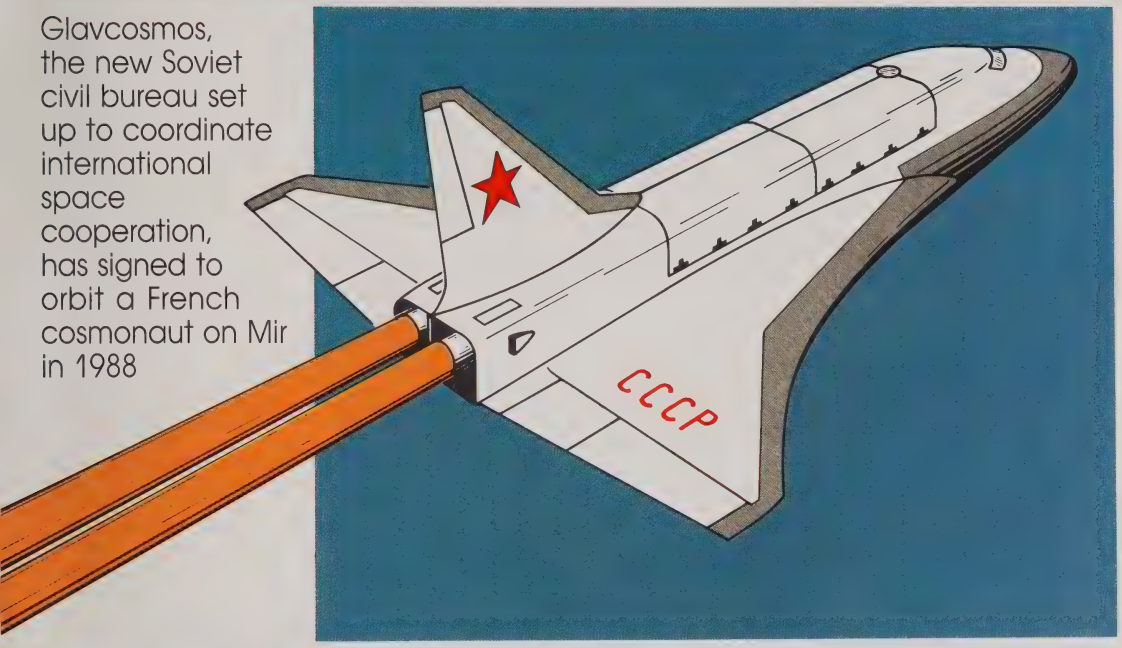
SOVIET AIMS INCLUDE EXPANDING INTERNATIONAL SPACE PARTICIPATION AND STREAMLINING MANAGEMENT

Glavcosmos, the new Soviet civil bureau set up to coordinate international space cooperation, has signed to orbit a French cosmonaut on Mir in 1988



Soviet space shuttle orbiter is equipped with jet engines, which will give the Soviet shuttle greater flexibility in handling landing situations when returning from space than the U. S. has.

Jeffrey M. Lenorovitz/Moscow

The Soviet Union is far from undertaking commercial space programs as we know them in the West, but the country has been working to widen the scope of its civil space programs by increasing emphasis on international cooperation and streamlining program management.

The main attempt at a Western-style Soviet commercial space effort was the country's unsuccessful offer in 1983 of the Proton launcher to orbit second-generation communications satellites for the International Maritime Satellite Organization. The Soviet Union is one of the largest participants in the London-based Inmarsat, and this gave the country a good starting point from which to make its first tentative move into the commercial launcher field.

Inmarsat ultimately selected the U. S. space shuttle and Europe's Ariane launcher to orbit its satellites, and the Soviets are not known to have made any other serious offers on a large scale since then.

"Realistically, it's going to be difficult for the Soviets to develop a commercial service because of the secrecy surrounding their launcher efforts and because of concern about allowing the technology of a Western satellite to fall into their hands," a manager for one European satellite manufacturer said.

"They may be able to sign a commercial type contract from time to time with a country like India for a satellite launch, but this would be the exception rather than the rule," he said. "I find it difficult to imagine Hughes, RCA, Ford Aerospace, Messerschmitt-Boelkow-Blohm, Aerospatiale or other Western manufacturers handing over an advanced communications satellite to the Soviets for launch, let alone finding a Western government that would allow this to happen in the first place."

The Soviet Union has, however, tried to step up cooperation on space programs for scientific and research purposes, and it recently formed the Glavcosmos organization to coordinate such cooperative efforts with other countries.

One of Glavcosmos' first formal actions was the signing in March of an agreement with France's CNES national space agency for the long-duration flight of a French cosmonaut on the Soviet Mir space station in 1988. This mission follows the 1982 flight of Frenchman Jean-Loup Chretien on the Salyut 7 space station.

"Until the creation of Glavcosmos, the Soviets really didn't have a central civil national

space organization such as NASA, CNES or the Japanese NASDA," one French space program official said. "There are two institutes in the Soviet Academy of Science that deal with space matters—the Space Research Institute and the Vernadsky Institute of Geochemistry and Analytical Chemistry—and neither had high-level decision-making power."

Glavcosmos, however, should have the power to make program decisions and act as the contact between Soviet industry and Soviet laboratories, as well as becoming involved with cooperative programs on the international level.

According to Roald Sagdeev, director of the Space Research Institute, Glavcosmos should trim back the number of contacts necessary between his institute and the Soviet industry that builds the spacecraft.

"When we contracted in the past with our industry for spacecraft, systems or subsystems, we had to deal with individual companies," Sagdeev said. "The role of Glavcosmos is to act as a top-level body. We would give it an overall contract, and it then would work with industry."

Valery Barsukov, director of the Vernadsky Institute, said one of Glavcosmos's key tasks should be to make contacts between Soviet industry and foreign countries in the framework of cooperative programs, instead of having this done on the ministry level.

A series of unmanned scientific planetary space flights are planned by the Soviets in the coming years, and the country has expressed its willingness to cooperate with other nations on developing payloads for the missions.

"The Soviets are taking a very active role in seeking international partners for several reasons, including the fact that it allows them to reduce their financial burden since a part of the scientific payload is provided by other countries. This also gives them the chance to incorporate advanced technology developed by other nations," one U. S. scientist said. "The Soviets are taking the advantage by showing their willingness to cooperate at a time when the U. S. planetary space program is not as active, and the Soviets are attracting a lot of interest from the world's scientific community—including U. S. specialists who are seeking new missions in which to become involved."

The Soviet Union has been performing a wide range of space processing experiments on its Salyut space station, and this activity is expected to increase significantly with the new Mir station launched earlier this year. The Soviets' goal is to have continuous activity on board Mir, made possible by routine rotation of crews. This gives cosmonauts the opportunity to perform extended experiments in such areas as crystal growth and other types of materials processing.

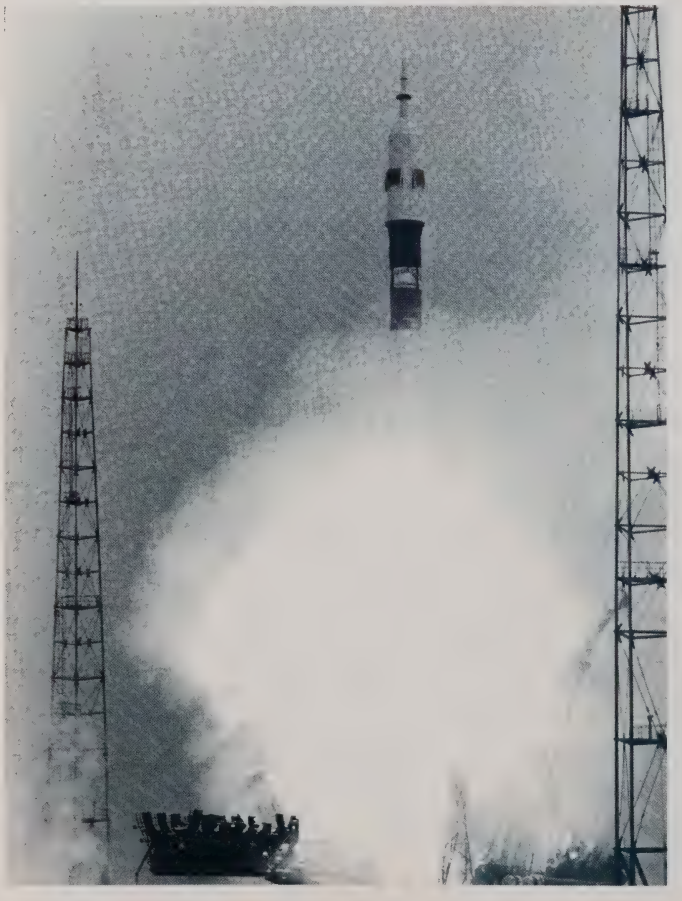
Until the NASA international space station enters operation in the 1990s, the U. S. and its Western allies will have to be satisfied with the week-long average duration of shuttle flights.

The Soviets have gained experience in construction and repair of space-based facilities, both in practice situations and real cases where problems have forced serious in-orbit troubleshooting. Soviet cosmonaut Svetlana Savitskaya, during a 1984 EVA, cut, welded and soldered metal samples outside the Salyut station and she sprayed silver on a plate.

Savitskaya said a series of electrophoresis experiments have been performed inside the Salyut station as part of evaluations on processing pharmaceutical products in space.

The Mir station significantly increases the Soviets' capacity to perform research and development work in space since the Mir can accommodate four building-block modules. Soviet officials said each of the modules may be dedicated to individual science disciplines such as biology, astronomy and space processing. Mir also has two more docking ports for the Soyuz/Progress type vehicles that are used to transfer crewmembers and supplies to the station.

"The Soviets are going to give a nonstop show aboard Mir, and we're going to be on the sidelines," one U. S. industry manager said. "You can say what you want about the Soviets not being as technologically advanced as the West, but when you get down to it, they now have the capability for a permanent orbital station, while we're still working on paper for ours." ●



Soyuz T-15 is shown as it lifted off this spring, carrying cosmonauts Leonid Kizim and Vladimir Solovyov.

CHINESE SPACE PROGRAM BOASTS MODERN FACILITIES

Modern Chinese facilities at the new Xichang launch site southwest of Chengdu include a large range control center (right) and precision guided optical tracking cameras (bottom right) to film the launch of Long March 3 boosters. The large range control center at Xichang is about three miles from the launch pad. Countdowns for the Long March 3 booster are monitored here, but conducted from a blockhouse much closer to the launch pad. In addition to this range control room, the facility has large computer rooms using redundant parallel computers operated by army personnel. An older space tracking facility (bottom left) at Weinan is used to communicate with the two Chinese spacecraft in geosynchronous orbit.

Redwoods, Bull Creek Flat, Northern California. Photograph by Ansel Adams. Courtesy of The Trustees of The Ansel Adams Publishing Rights Trust. All Rights Reserved.

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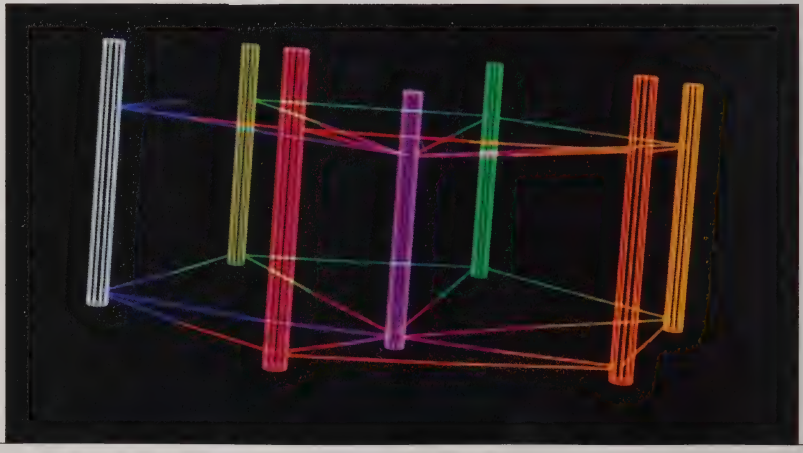
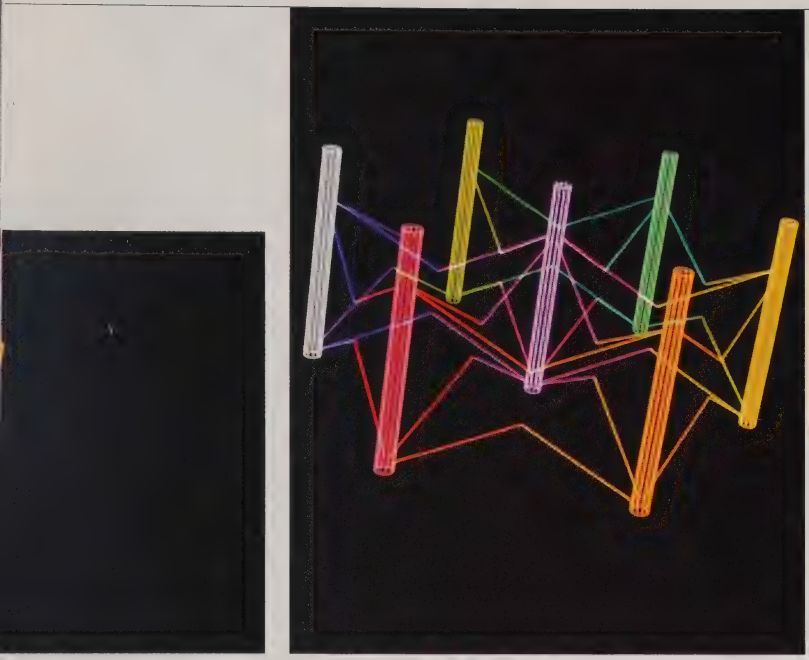
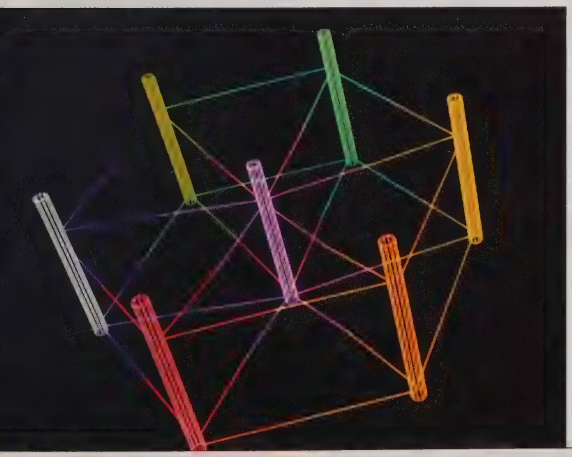
COMPUTER IMAGES AID ANTENNA DESIGN

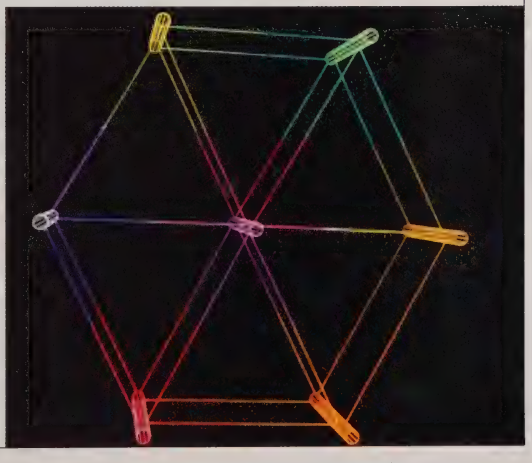
This colorful computer-aided design (CAD) photo series demonstrates how a large deployable antenna being studied by France for use on future telecommunications satellites would be unfurled in space. France's studies are aimed at evolving a 4 to 40 meter-diameter (13-130-foot-diameter) antenna reflector able to operate from 1 GHz. to 20 or 30 GHz., which could be stowed compactly for launch, then opened in space to form a strong,





accurately shaped antenna. The photos show the deployment from initial opening, starting at top left, to the fully extended final position at bottom right. This work is being performed by Aerospatiale and Alcatel-Thomson Espace under contract to the French CNES national space agency. Skin of the reflector would be a metallic mesh fitted on the deployable truss, and the radio-frequency active surface would be made of gold-plated molybdenum mesh. In addition to the antenna evaluations performed with computer-aided design images such as these, Aerospatiale has conducted deployment tests using representative hardware at the company's Les Mureaux facility outside Paris. One application studied for the deployable antenna is on the M-Sat type of spacecraft planned by Canada for communications with mobile Earth station terminals.





ELV MAKERS GEAR FOR PRODUCTION RESTART

A new national policy, dictated by recent losses, emphasizes a mixed fleet of expendables and man-rated shuttles

Keith Mordoff/Los Angeles

American expendable launch vehicle (ELV) manufacturers have been preparing production, launch and cost estimates for restarting and, in one case, increasing production of their boosters as a result of the loss of the orbiter Challenger on Jan. 28.

Several government agencies, the military and potential commercial customers have asked for the estimates, as users of launcher capabilities struggle to find alternate ways into space and reestablish launch schedules made obsolete by the grounding and 25% reduction of the orbiter fleet. Recent failures of two expendable launchers, the Delta and Titan 34D, have forced groundings of these two systems, postponed a planned May 22 Atlas/Centaur launch and added further confusion to the near-term, U. S. launch capability shortage.

Before Challenger's destruction two expendable launch vehicle manufacturers in the U. S. had seen their booster production lines finally come to a halt and a third remained open only to fill significant, but low volume, orders from the U. S. Air Force.

Though efforts had been made to sell launch services commercially, the vehicles were being forced out of the market mainly by a space shuttle/Ariane price competition they could not contend with. Marketing efforts continued in the hope that additional launch capability would be needed to support the Strategic Defense Initiative and space station requirements, but these efforts so far had been unsuccessful.

Last fall, William F. Rector, 3rd, vice president of program development for General Dynamics' Commercial Space Systems Div., said, "There will be an overflow beyond shuttle and Ariane, and that's what we are banking on."

The overflow has now grown considerably.

The results of the Challenger loss—launch delays and a three orbiter fleet capable of far fewer annual missions—have reopened the ELV production options. The National Aeronautics and Space Administration, USAF and several foreign organizations have asked ELV manufacturers about their launchers' capabilities, how soon the vehicles could be made available and at what price. NASA also has asked Rockwell International to provide cost figures for building one or two additional orbiters.

A new national launch policy is developing that will leave room for a mixed fleet of ELVs and space shuttles. Such a policy is being advocated strongly by some NASA officials, while others see expendables relieving the shuttle launch burden as only a short-term solution.

"We hope to see the U. S. establish a healthy, viable and competitive commercial ELV capability," acting NASA Adminstrator William R. Graham told a House panel.

A change in the launch policy would help improve the commercial viability of manufacturing U. S. ELVs, but renewed production orders

U. S. manufacturers of expendable launch vehicles may see their assembly lines filling with new production boosters if our national launch policy develops to include a mixed fleet of expendables and space shuttles. The end of the McDonnell Douglas Astronautics Delta launch vehicle assembly line in Huntington Beach, Calif., looked like this before production closed in 1984.

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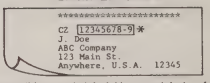

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from NASA would signify a reversal in policy that called for total reliance on the shuttle by NASA and phase-out of the expendable vehicles.

Graham already has ordered that no additional commercial communications satellites be launched from orbiters once the existing contracts have been met. The order forced NASA in March to end launch service negotiations with several customers, including Arabsat, the British Defense Ministry, Eutelsat, Italsat, RCA and a Mitsubishi/Ford satellite consortium.

The order pushes customers to seek launch services from Arianespace, Japan, China or possibly the Soviet Union. Many NASA officials believe that Arianespace will be able to capture the entire market, although it is difficult to determine whether Ariane production and launch frequencies can be increased enough to do so.

Alan M. Lovelace, vice president and general manager of General Dynamics' Space Systems Div., in a Mar. 6 address before the House subcommittee on space science and applications, said, "Based on the results of our study, it is our firm belief that if the United States space program is to meet its current commitments, government procurement of a diversified fleet of ELVs is absolutely essential."

Louis C. Raburn, director of Delta programs for McDonnell Douglas, agreed.

"I think there is room for several vehicles and a need for a mixed fleet in this country. An 18-24-month delay in shuttle operations is likely. Having lost that many slots even with building an additional shuttle, there will still be a large shortfall in the next five or six years."

With the emerging mixed fleet policy, a NASA order for at least one new orbiter and new orders for additional ELVs from the Air Force are expected this year.

Martin Marietta has some advantage over McDonnell Douglas or General Dynamics by being the only active U. S. manufacturer of new launchers at this time. Martin Marietta's large Titan 34D-7 complementary expendable launch vehicle (CELV) is in low-volume production for USAF and the vehicle's high payload weight to orbit capability is needed to supplement the shuttle.

The company also is considering placing its Titan 34D back into production for the Air Force and the service may increase its order for the larger Titan 34D-7 beyond the planned number of 10. The standard 34D is capable of placing a 4,100-pound payload into geosynchronous orbit from a Cape Canaveral launch and the 34D-7 is designed to lift 10,000 pounds into the same orbit.

The nation's inability to place large military payloads into orbit has been severely magnified, however, by the second straight failure of a Titan 34D, which adds to the heavy launch vehicle gap left by the shuttle's inactivity. The Apr. 18 Titan explosion just after liftoff from Vandenberg AFB, Calif., may end the service's capacity to launch imaging reconnaissance, missile early warning and Defense Satellite Communications satellites for some time, pending the investigation.

Martin Marietta also is the prime contractor for refurbishing and modifying Titan 2 intercon-

Martin Marietta production of Titan 34D-7 complementary expendable launch vehicles probably will increase as a result of the loss of the space shuttle Challenger. A Titan 34D, similar to the Air Force Titan 34D recently lost at Vandenberg AFB, Calif., is shown above on its Cape Canaveral launch pad.

tinental ballistic missiles (ICBMs) for launching small payloads. The Air Force expects to convert 56 missiles into launchers once their deactivation from service is complete.

McDonnell Douglas and General Dynamics no longer have their Delta and Atlas launchers in production, but have the capability to roll out new vehicles in two or three years if orders are received.

"We have the ability to get Delta back into production easily," Raburn of McDonnell Douglas said. "All we need is the authority to begin. We could launch the first new production bird in about 23 months."

General Dynamics estimates that it could launch its first new Atlas/Centaur vehicle in about 30 months.

A General Dynamics study conducted shortly after the Challenger loss listed, prioritized and classified planned orbiter payloads that had been scheduled for launch through 1989. The study determined that of 186 total shuttle payloads during that time, only 83 required the shuttle for launch.

"The other 103 could easily go on ELVs," Rector said. "Some satellites were designed from the start to be launched on the shuttle or an expendable."

An overflow analysis from the study determined that whether the shuttle was grounded from 12 to 24 months was not as significant as the fact that only three orbiters would be available to launch payloads and the flight rate would be reduced. Delays of 12 and 24 months would result in 70 and 82 extra payloads respectively, according to the study.

"The time at which the shuttle launches resume is not the big driver," Rector said. "It's the fact that we have lost an orbiter."

Atlas production at General Dynamics has ceased, but one of three remaining Atlas G/Centaur launch vehicles is being readied for a launch from Cape Canaveral Air Force Station (shown below and on facing page). The vehicle had been scheduled to launch a U. S. Navy FleetSatCom satellite from Florida May 22. General Dynamics has supplied data to several potential customers about reopening the Atlas production line and has completed studies on a stretched Atlas and growth Atlas/Centaur derivatives.

The study prioritized all upcoming payloads by launch need as follows:

- Large national security payloads.
- Large National Aeronautics and Space Administration payloads, including space telescope and Galileo.
- Global positioning system (GPS) satellites.
- Shuttle unique payloads, including scientific and material processing type payloads.
- Small government satellites, such as National Oceanic and Atmospheric Administration and geostationary operational environmental studies (GOES) satellites.
- Commercial communication and foreign satellites.

The payloads then could be arranged by the types of ELVs capable of launching them. These include Delta, Atlas and Titan 2s for the smaller payloads, Ariane and Atlas/Centaur for the medium-class sizes and Titan/Centaur for the largest, according to the study.

Current opinions have the highest-priority payloads and shuttle-unique payloads taking up most of the shuttle missions for the foreseeable future. With commercial satellites in general appearing low on shuttle launch priority lists and if present NASA policy holds, more ELVs of the small and medium-class size will be necessary to fill the void. Arianespace marketing efforts, for example, already have increased and negotiations with some of the launch customers left stranded by the hold in shuttle operations are nearing completion.

Acting Air Force Secretary Edward C. Aldridge, Jr., also has advocated suspending commercial satellite flights from the shuttle orbiters once all present commitments are met. Aldridge has submitted a proposal to the White House Senior Interagency Group for Space that would have the Air Force procure a large number of medium-class ELVs for launching medium-size defense satellites. These vehicles would be procured in addition to the USAF orders placed for CELVs and the refurbished Titan 2 launchers.

Another requirement of the selected Air Force medium-class launcher would be its ability to compete commercially with Ariane. A 4-6 per year launcher buy envisioned by the Air Force would establish a solid base from which to develop a commercial product.

One potential plum identified by contractor payload/launcher studies and a prime mission for the Air Force medium-class launchers would be the launch of all or some of the 28 Block-2 Navstar satellites for the GPS. McDonnell Douglas, General Dynamics and Martin Marietta could supply boosters that could support the GPS mission, once totally dedicated to the shuttle. Shuttle GPS launches were scheduled to begin in January, 1986.

General Dynamics' last production vehicle, the Atlas G/Centaur or a stretched Atlas, called Atlas K, could be offered for the GPS requirement if a competition materializes. The Atlas K would incorporate a stretch to the main Atlas G tank and utilize a small solid or liquid upper stage. The Atlas/Centaur combination was studied for the GPS launches in 1972 by General Dynamics before the decision to launch them on the shuttle was made, Rector said. The compa-

ny still considers the vehicle a valid candidate for GPS.

A larger Super Atlas G/Centaur vehicle also is under study for potential customers. The vehicle would incorporate four Star 31 strap-on motors, a 20% growth in Atlas propellant tank capacity, extendable Centaur nozzles and an optional larger spacecraft fairing. The Super G would be in the same size class as the Ariane 3, Rector said.

General Dynamics believes that by 1988 it can build three Atlas or Atlas/Centaur launch vehicles and five each year from 1989-92. Additional investments in tooling and upgrading launch complexes could boost production to nine vehicles in 1989 and 17 vehicles per year by 1990 if there were such a requirement, according to Lovelace. Atlas production is paced by the supply of main engines, Rocketdyne MA-5s, for the vehicles.

Centaur production continues as the upper stage for the Titan 34D-7 and for the shuttle, though planned shuttle operations with the liquid upper stage are being reviewed. The current Centaur production schedule calls for two deliveries this year, four in 1987, three in 1988 and five per year starting in 1989.

Three remaining Atlas G/Centaur vehicles are scheduled to launch three Navy FleetSatCom satellites. The first launch, planned for May 22, was delayed by NASA as a result of the Delta failure investigation. The Delta's Rocketdyne RS-27 propulsion system and the Atlas Rocketdyne MA-5 propulsion system share some design similarities that warranted a hold of the launch until a better understanding of the accident is reached.

Other Atlas vehicles in the government inventory include one Atlas H and 12 Atlas Es being refurbished for launches from Vandenberg.

McDonnell Douglas could launch a modified Delta 3920 vehicle to carry the basic 1,850-pound Navstars by July or August, 1987. An upgraded version of Delta, incorporating a 12-foot stretch, could be available by January, 1989, for launching the 2,050-pound upgraded Navstars.

The Astronautics Div. of McDonnell Douglas, Huntington Beach, Calif., delivered the last Delta launcher in December, 1984. Three Deltas remain in the inventory following the May 3 failure of the Delta 3914 launcher with a GOES weather satellite payload. The schedule, at this time, still calls for a classified SDI mission launch in August, another GOES launch in October and another SDI launch next year. Delays resulting from the failure investigation will likely change these launch dates depending on the severity of the problem.

McDonnell Douglas has components to build two Deltas and miscellaneous components for several more, according to Raburn.

"The long pole in building additional new Deltas is production of the Rocketdyne RS-27 main engine," he said. "We are having discussions with Rocketdyne and are studying how the delivery schedule could be speeded."

Main engines exist for building five new Deltas, he said.

Most of the Delta tooling is still in place at Huntington Beach. The normal maximum Delta assembly rate would be 11-12 vehicles per year, though it would take about two years to achieve that rate, Raburn said.

"We have proposed a six per year delivery schedule at this time based on the engine deliveries," he said. "We have plans to do more if needed."

Transpace Carriers, the company that has attempted unsuccessfully to market the Delta for two years, may have an easier time signing its first customer with the shuttle grounded. However, the company has yet to reach an agreement with NASA to take over the commercial Delta program and continues to operate on the basis of 60-day extensions to the original temporary NASA agreement. The company also has had problems completing its financing.

"The agreement they have now was based on conditions they haven't met—demonstrated technical ability, signing up customers and so forth," a NASA official said. "Transpace needs an agreement that they can be the operator of the system."

David Grimes, Transpace Carriers president, told a congressional panel that Transpace could have two Delta vehicles available by September and November, 1987, four in 1988, seven in 1989, ten in 1990 and 12 per year beginning in 1991.

The company is asking $30-35 million for the Delta, up from a $20-million figure offered to some customers last summer.

Transpace had planned to use the spare Delta vehicles and remaining components, now dedicated to the SDI missions and other users, while NASA maintains the hardware is government property.

Grimes complained to Congress about NASA's decision to make the vehicles available to the Defense Dept. and said the action had "very severe repercussions in the marketplace for TCI." If the government decides to operate Delta launchers concurrently with TCI or during a transition period to commercial operations, TCI's opportunity to commercialize Delta will be "effectively ended," Grimes said.

McDonnell Douglas has supplied Transpace with data and quotes for its marketing efforts and maintains that it does not care whether it sells Deltas to the Air Force, NASA or Transpace.

"The problem we have is with third party liability issues," a McDonnell Douglas official said. "Until that is resolved, it will continue to be a big problem in all industries."

Several small, private companies also still have active efforts to develop their own new commercial launch vehicles, though it is doubtful that the shuttle accident will result in any significant boon for the programs. The uncertainties and time necessary to develop reliable launchers, insurance difficulties and other ELVs put back into production would hinder the development of any all-new vehicles at this time. It also is doubtful that many customers will be willing to step forward and accept the risks that would come with a new launcher considering the launch failures that have occurred with the established programs. ●

Even if an additional shuttle is built, there will still be a large shortfall in space launch capability for the next five or six years

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BUDGET CONSTRAINTS FORCE NASA TO SCALE BACK SPACE STATION PLAN

Washington

The space station earlier envisioned by NASA has been reduced in scale, but many elements of the original plan survived largely intact in the final baseline configuration that station officials endorsed this spring. After the ninth space shuttle mission launched for station assembly, NASA will be ready to permanently man the platform, fulfilling a primary objective of President Reagan's mandate.

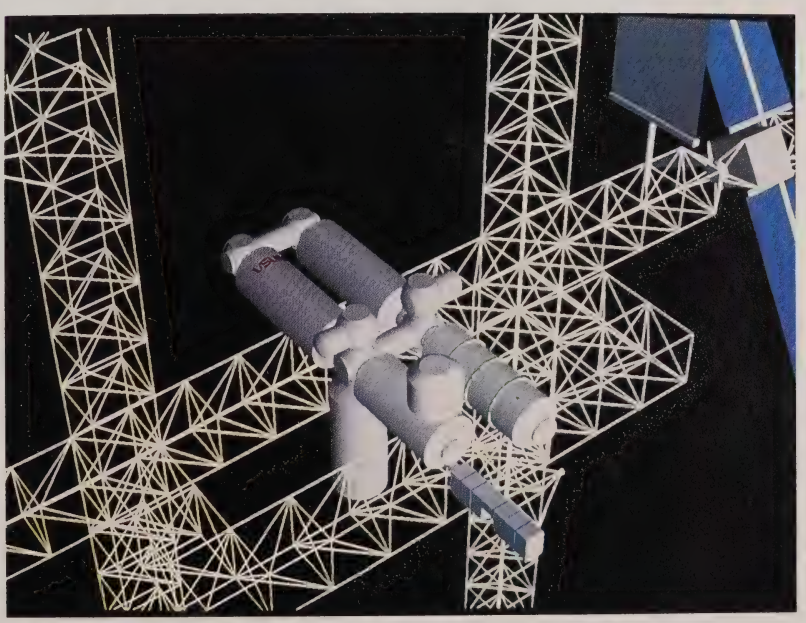
Budget constraints have already delayed some station elements, and other parts planned for use in 1994 are almost certain to fall victim to future cuts. Nevertheless, space station officials remain optimistic about meeting their goals.

"By 1994, we will have a respectable, useful, fully manned permanent space station," John Hodge, NASA's acting associate administrator for the space station, told a House subcommittee in April. The following elements will be included in the station in 1994, a milestone NASA calls initial operating capability (IOC), as a result of definition studies completed in March:

- **Pressurized modules.** The U. S. will provide two at IOC, not four as planned earlier. The original module concept was shorter and included a 10-foot-long interconnector. The interconnector is separate from the new module, so the pressurized volume is nearly the same. The station will have four modules—two from the U. S., one from Europe and one from Japan. All of them will be outfitted with identical racks to allow easy changeout of equipment and experiments.

NASA also assigned module functions to the international station partners. The U. S. kept the microgravity processing function, as directed by Edward Boland, a Democratic representative from Massachusetts, in January. The Japanese module will be used for advanced technology and the European one for life sciences. The Europeans are dissatisfied with their assignment since they have focused much of their space applications efforts on materials processing.

- **Truss size.** The length of the struts that will be assembled manually in space into structural bays has increased from 9 feet to 5 meters (16.4 feet).
- **Platforms.** Four free-flying platforms will be launched, two provided by the United States and two from Europe. Two will fly in the same equatorial orbit as the station and two will be placed in polar orbit.
- **Servicing area.** Only one major bay for satellite servicing will be included in the initial



Baseline configuration recommended by the NASA space station office contains four modules—two from the United States, one from Europe and one from Japan.

JAPAN AND CANADA DECIDE ON STATION ELEMENTS

ESA DISCUSSES REMOVABLE COLUMBUS MODULE WITH NASA

Japan and Canada reached agreements with NASA in March on the hardware elements each would study during the preliminary design phase of station development, which will end in January, 1987.

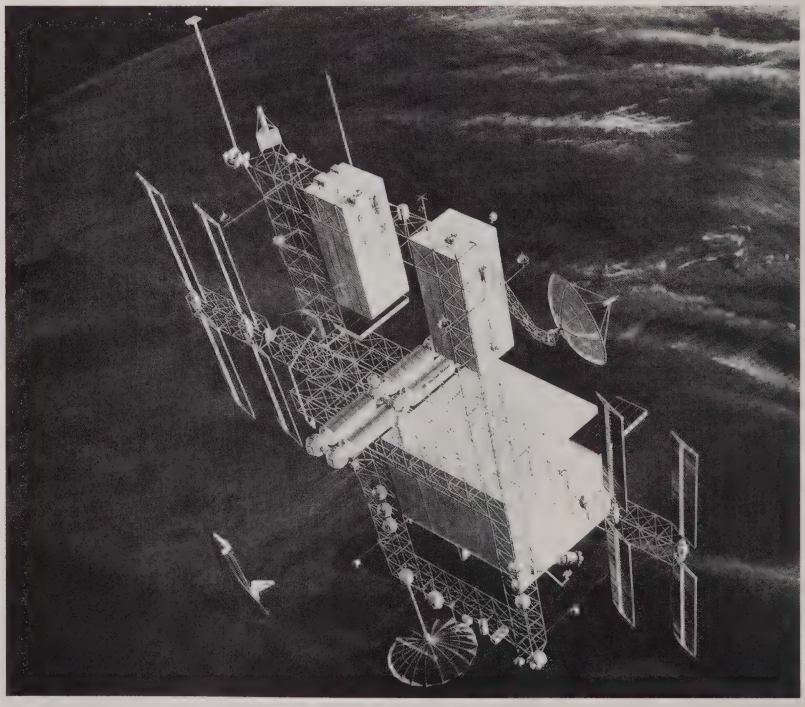
The European Space Agency missed the deadline due to a dispute with NASA over whether the Europeans could detach their pressurized module from the rest of the station. ESA and NASA were still negotiating earlier this month, but NASA officials said they were confident an agreement would be reached.

Japan will provide a multipurpose research and development module. The lab will provide a work area, a scientifiic/equipment air lock, a local remote manipulator arm and a logistics module.

Canada will design a Mobile Servicing Center that will be able to move around the station's exterior for assembly and maintenance and payload servicing.

configuration. NASA would have preferred two bays, to keep "clean" tasks, such as instrument refurbishment, separate from "dirty" ones, such as refueling operations. The Canadian mobile servicing center also will have a hangar, but that will be used primarily for servicing the mobile manipulator.

- **Power.** NASA officials have selected a hybrid power system that will provide 75 kilowatts. After debating the merits of solar voltaic versus solar dynamic power, NASA officials opted for a mix of the two. Solar voltaic cells will provide 25 kilowatts of power, while the solar dynamic system will provide 50 kilowatts. The solar voltaic system will consist of arrays with cells that collect energy when exposed to sunlight. The solar dynamic system, to be used for the first time in space on the station, will have six-sided dish-shaped mirrors to collect energy to run a heat engine that will generate electricity. The solar dynamic system will cut down on the amount of aerodynamic drag that would be incurred by additional larger solar panels.
- **Life support system.** For the first time in the U. S. space program, a manned system will use a closed-loop environmental control and life support system. Oxygen and water will be recycled; nitrogen and food will be resupplied at least four times per year. The atmosphere selected for the station will simulate sea level conditions in pressure and composition.
- **Station altitude.** The station will be assembled at 220 nautical miles and operated at 250 nautical miles, instead of the 270 nautical miles originally planned. This will lower launch costs, but increase the cost of propellants required to keep the station in the proper orbit.



An earlier dual-keel design (right) included two small bays and one large bay for servicing operations that require a closed environment, such as fueling and satellite repair. A McDonnell Douglas rendering (opposite page) shows a robotic arm being controlled by an astronaut to position a node that allows another pressurized module to be added to the station.

■ **Propulsion.** Hydrazine was selected for attitude control and altitude reboost.

■ **Orbital Maneuvering Vehicle.** The station will have its own OMV to move payloads around in the vicinity of the manned base. The OMV will be returned to Earth for refueling and maintenance. Station officials estimate it will spend 50 percent of the time in space during IOC. The vehicle will be a carbon copy of the shuttle OMV and will be included as an option in the shuttle OMV contract that will be awarded in June (CSWinter 1986, p. 9).

■ **Crew.** The station will be able to accommodate six to eight astronauts at IOC. The mission duration will range from 45 days to 6 months.

■ **Instrument ports.** Five ports, down from an earlier projection of nine, will provide utilities and mounting positions for a major instrument or cluster of instruments. NASA has not decided what instruments will be mounted during IOC nor how the ports will be divided among international partners.

■ **Extravehicular activity.** Shuttle spacesuits will be used for early station assembly operations, and an advanced space station suit will be introduced by the ninth assembly flight. Improvements of the station suit over the current suit will possibly include higher pressurization and hardening to protect against radiation. A goal of the advanced suit program will be to allow suits to be sized to fit various crewmembers and serviced on the station, eliminating the requirement for frequent returns to Earth. NASA is looking at a buy of six station suits.

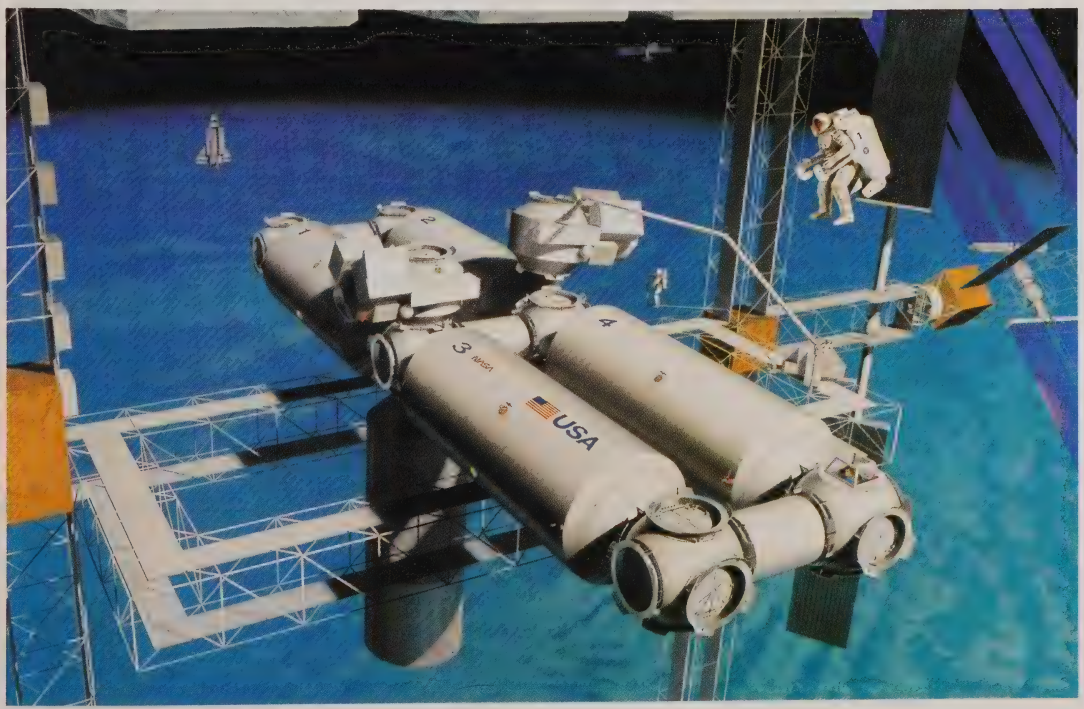
The four NASA centers that have been assigned space station development responsibilities will have some of their tasks altered this summer. NASA headquarters is preparing changes to the four work packages held by Johnson, Lewis, Marshall and Goddard centers to tighten a management approach that has resulted in substantial design overlaps.

NASA managers this spring considered and rejected a proposal to take station responsibilities from the Marshall, Lewis and Goddard centers and centralize them at Johnson. The one center/one contractor approach, favored by Johnson managers, was one of two options considered by space station management in March.

These two options were aimed at eliminating overlap between centers before NASA and its contractors began to devote costly engineering hours to the station in the preliminary design phase.

NASA is almost certain to receive substantial cuts to the space station budget beginning in Fiscal 1987. The Senate Budget Committee in March tried to freeze the station's Fiscal 1987 budget at the Fiscal 1986 level of $195 million. Another possibility often mentioned by congressional staffers and lobbyists is to delay the station by a year or more and use the money saved to buy an orbiter to replace the Challenger, which was destroyed Jan. 28. Space station managers are under substantial pressure to find cost savings in the program wherever possible, and work package overlap is an area that can be streamlined to save money.

Richard Carlisle, NASA space station deputy director for engineering, said the parallel efforts



NASA TO SELECT NEW SPACE CENTERS

GROUPS WILL CONDUCT HIGH-TECHNOLOGY RESEARCH

The National Aeronautics and Space Administration will select a second group of research and technology centers in late June to become Centers for Commercial Development of Space. Five were selected last year in the first round of the program.

As many as seven proposals from industry/university consortiums will be selected to receive annual funding for up to five years to conduct high-technology space research. NASA will provide $500,000-1 million annually to the centers, which are expected to match or exceed that sum.

The following 25 institutions submitted proposals in April:

- Florida Institute of Technology, Research & Engineering, Melbourne, Fla.
- Clarkson University, Potsdam, N. Y.
- Southwest Biotechnology Center, Albuquerque, N. M.
- University of Massachusetts, Polymer Research Institute, Amherst, Mass.
- University of Wisconsin, Madison, Wis.
- Stanford University, Stanford, Calif.
- Worcester Polytechnic Institute, Center for Fire Safety Studies, Worcester, Mass.
- Midwest Research Institute, Kansas City, Mo.
- Texas A&M University, College Station, Tex.
- Aeroconsortium, Wrightwood, Calif.
- Tulane University, New Orleans, La.
- University of New Mexico, Center for High Technology Materials, Albuquerque, N. M.
- Weber State College, Center for Aerospace Technology, Ogden, Utah.
- Georgia Institute of Technology, Atlanta, Ga.
- University of Houston, Houston, Tex.
- Southeastern Massachusetts University, North Dartmouth, Mass.
- Ohio State University, Columbus, Ohio.
- Case Western Reserve University, Cleveland, Ohio.
- University of New Mexico, Technology Application Center, Albuquerque, N. M.
- Southeast Florida Educational Consortium, Miami, Fla.
- Woods Hole Oceanographic Institution, Woods Hole, Mass.
- Massachusetts Institute of Technology, Cambridge, Mass.
- Southwest Research Institute, San Antonio, Tex.
- Center for Innovative Technology, Herndon, Va.
- Clemson University, Clemson, S. C.

of the centers and resulting uncertainties has "grown into a monster" that needs to be cleaned up.

He cited the Marshall common habitable module as an example. In planning the module, Marshall became involved with the system integration design of subsystems, including power, data and communications. But those subsystems are assigned to other centers.

The division of station responsibilities among four centers is inefficient and difficult to handle, Carlisle said. Station managers decided work package restructuring was needed and narrowed the options for reducing overlap to two:

- Strengthening Level B NASA management by increasing their technical skill and talent. Level B is made up of second-tier agency managers who are responsible for implementing the program defined by Level A senior managers.
- Moving toward a one center/one contractor approach.

While the second approach was endorsed by Johnson officials, NASA headquarters had reservations about concentrating station expertise in a narrow base. Because the program will run 20 years or longer and will dominate NASA operations in the 1990s, headquarters managers wanted to spread the station expertise over a broader base.

"We want to be as efficient as possible, while retaining corporate memory and systems engineering capability within the government," Carlisle said.

Preliminary design work on the space station began in April. Station managers wanted to have any possible work package restructuring decisions in place by then to avoid drastic changes that would have disrupted the eight contractor teams assigned to the four centers.

Managers believe concentrating station development at one center is probably a good idea strictly from a cost savings point. But other factors—the decentralized nature of NASA's organization and engineering expertise, the benefits of having a broad contractor base and the political support that can be gained by distributing the work around the country—argue against transferring the bulk of the work to Johnson, other managers said.

Space station officials still hope to begin operations by 1994, the date established by President Reagan, despite a realization that NASA probably will have less than $8 billion to build the platform. The station will not be as elaborate as envisioned at times during the last two years, but would fulfill the goal of a permanent manned presence. Station cost estimates will be based on the preliminary design work of the next nine months and should be available by the end of 1986. ●

NASA plans to streamline the management of station work packages, but not at the expense of the broad base of expertise provided by four individual development centers

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MACH 25:
THE UNITED STATES IS IN POSITION TO BREAK THE HYPERSONIC BARRIER

There was a young lady named Bright,
Whose speed was far faster than light
She set out one day In a relative way,
And returned home the previous night

Herbert J. Coleman/Washington

When Arthur H. R. Buller published that limerick in the British humor magazine "Punch" on Dec. 19, 1923, it is a safe bet that he did not have in mind flight at supersonic speeds—breakfast in New York and then breakfast again in Japan a little later—or an era which will make nonsense of the world's time zones.

In the United States, the long breather between cancellation of the U. S. supersonic transport, and abandonment of that new way of travel to Britain and France is over. National Aeronautics and Space Administration's quiet, low-key research into high-speed transportation is ready to pay off in a serious, funded program to build a transatmospheric vehicle with both civil and military applications.

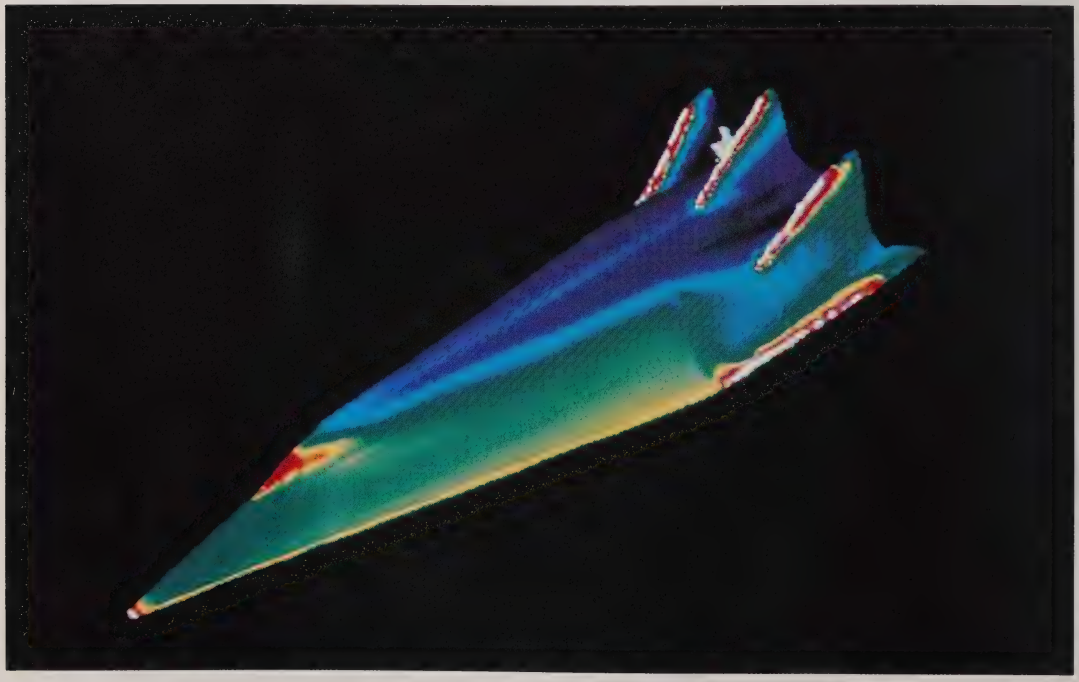
It has been talked about for years, by scientists and academia and by airline passengers and the people who run the airlines, and the great barrier has not been sound, but money.

No one really knows what a Mach 15-25 machine will cost, but it is generally conceded that the technology to build a hypersonic transport is now here, is manageable, and although it contains high risk areas, can be achieved in present-day laboratories.

Equally important, the U. S. project—unlike the late supersonic transport—is heavily backed by the Department of Defense, which sees a variety of applications for operations in the transatmospheric regions. Another plus leading to development of the aerospace vehicle is active participation by the Strategic Defense Initiative Organization.

A program that had long been one for aficionados—call them dreamers—become vitally real when President Ronald Reagan told the nation that his administration fully backed development of the National Aerospace Plane Program (NASP) and that he personally had given the go-ahead for the now famous Orient Express.

The Orient Express, envisioned as a 300-passenger airline transport to serve the Pacific Rim and its burgeoning business interest, is a name invented by two of the aficionados—Dr. Gus Weiss, a senior technical adviser on the White House staff, and one of America's noted test



pilots, A. Scott Crossfield, an X-15 pilot who now is senior technical consultant to the House Committee on Science and Technology.

Both are nonplussed that the name Orient Express has been quickly adapted to exotic restaurants and less exotic delivery services, but as Crossfield put it: "If that is what it takes to put this great venture across to the nation, so be it."

Along with the rest of the technical community, Weiss and Crossfield see the key technology as integration of the engine with the airframe. In response to this, NASA and Department of Defense have recently issued development contracts to General Electric and Pratt and Whitney, with advanced technology pioneers at Aerojet Techsystems and Garrett's AiResearch Div. working closely with General Electric. GE has spent about $4 million of company funds on advanced technology engine research and development.

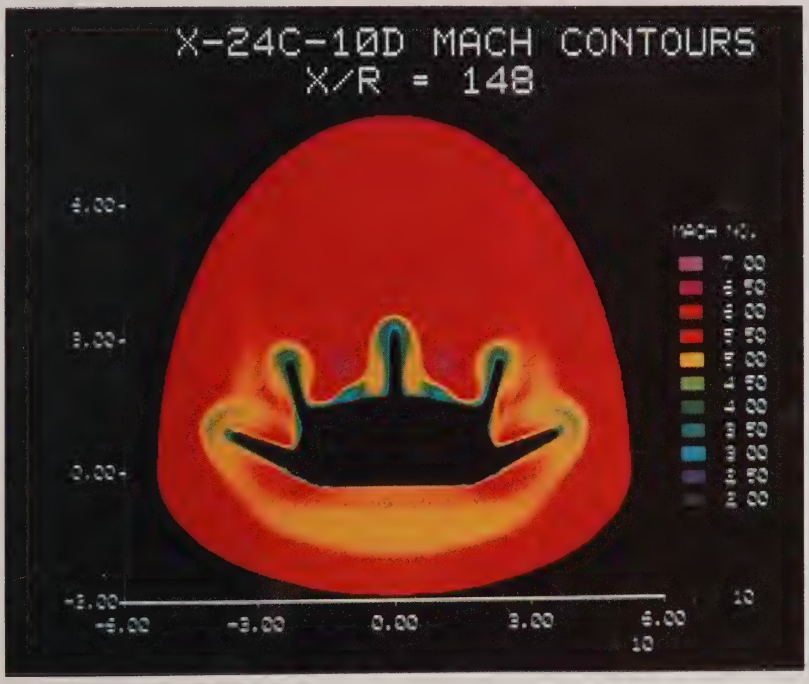
For starters, the backers are talking about funding in the neighborhood of $425 million, all of it currently being disbursed under the National Aerospace Plane Program as set up by NASA and the Defense Advanced Research Projects Agency (DARPA).

The airframe contracts, each with a potential value of up to $32 million, have gone to Boeing, General Dynamics, Lockheed, McDonnell Douglas and Rockwell International. Within a year or so, this group will be pared to two or three contractors in a design competition leading to construction of an experimental aerospace plane, scaled down to a flight test article for the testing of engines and materials in the transatmospheric regime in which it will eventually operate.

The National Aerospace Plane Project is turning into something peculiarly American—the technology is here, so use it. It is also peculiarly American in that NASP is a response to serious competition from Britain and France, both of which have a wealth of commercial supersonic experience with the Anglo-French Concorde Mach 2.2 transport, now in its 11th year of passenger operations.

There are some U. S. scientists and manufacturers who welcome the European competition, not only as a spur to a formidable American hypersonic drive, but as a future high-technology pool in which nations will join nations in a giant consortium to build a single vehicle.

British Aerospace is well into design of its



Computer techniques in design of hypersonic vehicles were used at Wright-Patterson AFB, Ohio, in development of the Martin-Marietta and Lockheed families of X-24 vehicles, starting with early lifting bodies for the space program reentry techniques. A Cray supercomputer also is being used in development of the Advanced Turbo Rocket engine at Aerojet TechSystems. The computer simulation shown on the X-24C-10D is for Mach 6 flight.

HOTOL (horizontal takeoff and landing vehicle), itself a competitor to the Orient Express in that it calls for London/Australia services taking an hour or so. HOTOL will be powered by liquid oxygen and hydrogen engines, a development currently kept under tight secrecy by Rolls-Royce.

Across the English Channel, Aerospatiale—the partner with British Aerospace in developing and building the Concorde—stole a march on the British by quietly designing Concorde 2, again using existing technology to create a Concorde follow-on for British Airways and Air France.

Those activities are viewed with some concern in the United States. Norris J. Krone, a pilot and executive director of the University of Maryland's University Research Foundation, recently told the House subcommittee on transportation, aviation and materials, that tax legislation would be needed to partially counter increasing direct support given by foreign governments to support their aerospace industries. He went on: "There is no reason to believe that the [American] aerospace industry couldn't suffer the same fate as our shipbuilding industry did after World War 2, if we don't work to maintain the technology advantage which is the key to superiority of future products, maintenance of the national security and leadership in world sales of aeronautical products."

Speaking as ad hoc chairman of the American Institute of Aeronautics and Astronautics' advisory committee on national aeronautics, Krone said AIAA strongly supports the renewed interest in the hypersonic regime but warned that near-term subsonic and supersonic techniques are deficient and should be strengthened.

Early pre-space shuttle proposal to develop an orbital vehicle involved using the NASA/North American X-15, launched by Navajo boosters that had been mothballed when that program was cancelled. A proponent of this method of getting into space was A. Scott Crossfield, an X-15 pilot and now senior technical consultant to the House Committee on Science and Technology.

It is generally conceded that the hypersonic vehicles will have to operate in the lower fringes of space, and that the Concorde 2 is just that—an interim vehicle while the airlines watch closely to see if such seers as George D. Keyworth, the president's former science adviser, are right in that the Orient Express will fly to Tokyo and Hong Kong at fares comparable to today's.

The presidential announcement not only kicked off the program, it set in train ancillary activities—many company funded—to get aerospace firms into development of the thousands of devices and components that will be needed to make the project a reality.

The development, in one instance alone, will call for supercomputers that will be used to calculate the airflows vital to integration of airframe and engine. Critical technologies include heat treatment and computational fluid mechanics, all aimed at a flight test article that will explore the regimes at Mach 7+ speeds. Another area is in the fabrication of materials such as carbon-carbon and which will have to be bonded in large sections to lightweight metals such as beryllium.

But the entire program will depend on engine/airframe integration. The plan, as stated by the Department of Defense, is:

"If the new research program is successful in demonstrating the necessary technologies, an entirely new family of aerospace vehicles will be possible, able to cruise within the upper atmosphere at hypersonic speeds, or ascend directly into orbit. . . . As a space launch vehicle operating from conventional runways, the fully reusable and single state aspects of the NASP are believed to produce very large reductions in the cost to place payloads in orbit."

DARPA will keep leadership of NASP until the conclusion of the high risk technology validation phase and then will transition the activity to the U. S. Air Force for development of the flight test vehicle. NASA, the Air Force (including SDI), and Navy have set up a joint office for this at Wright-Patterson AFB, Ohio.

The President's National Commission on Space will recommend concentration on the National Aerospace Plane Program as vital in reducing costs of payloads flown to orbital altitudes. But there is a warning that the aerospace plane is a venture into high technology that will not be achieved quickly and that many years of highly intensive work remain before a passenger can have two breakfasts in a row.

Newest entry into the aerospaceplane field is Japan. Mitsubishi Heavy Industries, confident that a program of this magnitude will of necessity become the focus of an international collaborative team, has started design work on a hypersonic engine, using cryogenic technologies and liquid hydrogen fuels. This design envisions speeds beyond Mach 7 and Mitsubishi feels it can develop the powerplant to a thrust of 1.102 million. The engine would be 50 ft. long with a diameter of 14 ft.

National Aerospace Plane designs go back to early NASA designs leading to blunt body aerodynamic reentry shapes and this turned into a family of advanced aircraft such as the NASA/Briegleb M2-Fl glider and towed aircraft, the Northrop M2-F2 series and the Martin X-24A and B, air launched from the Boeing B-52 bomber and attaining speeds up to Mach 2.

Scott Crossfield recalls that in 1958 the North American X-15 high speed research aircraft team proposed an orbital X-15B that could be launched for $88 million.

"A pretty good bargain," Crossfield said many years later. "The X-15B would use boosters left over from the cancelled Navajo program. In the plasma jet tunnel we demonstrated that with beryllium oxide leading surfaces, we could withstand the reentry heat and have a turnaround orbital vehicle."

But the X-15B never got off the ground. About that time the Dynasoar lifting body program was cancelled and the X-15 itself ended up in the National Air and Space Museum in Washington, D. C. ●

NASA FINDS THE WAY TOWARD BUILDING A STATION FRAUGHT WITH LEGAL HURDLES

Internationalizing the new frontier of space is raising down-to-Earth political and legal questions

John W. Anderson/New York

Living in space is very difficult. Temperatures are extremely low and radiation extremely high. There is no oxygen to breathe, and if an astronaut gets in trouble, there is normally no spacecraft ready to come to his aid.

Yet the harsh environment is the least of NASA's worries in pursuing its latest space project, the permanently manned space station. Instead, the government agency is finding that the legal problems found in making the station a reality back here on Earth are proving just as formidable a task to conquer.

The United States, through NASA and the State Department, has been involved in active negotiations with the Europeans, Japanese and Canadians to build a space station by 1992 in time to celebrate the 500th anniversary of Christopher Columbus' discovery of America. But a delay in those negotiations, caused by differences as to how the station should be operated, coupled with budget cuts from the U. S., has delayed space station operations by at least two years to 1994.

The European Space Agency has offered to contribute $1.6-1.8 billion to the project, while the Japanese and Canadians have discussed giving another $1 billion and $600 million respectively, provided certain terms and conditions are met.

The Europeans want to build a laboratory module that emphasizes materials processing in space that can be separated easily from the main station. NASA has vehemently opposed this demand. NASA officials contend that such a move would not be a contribution by the Europeans to participate in the station, but instead a utilization of space station technology to learn the technical requirements of its infrastructure and then fly away to create a new European station. European officials disagree with NASA's assessment of their motives.

"We didn't mean to suggest that we would hook up to the station one day and then decide to sail away the next," Frederik Engstrom, director of space station operations at the European Space Agency, said. "We proposed that our Columbus pressurized module would be attached to the station, but that it be designed from the start to make short-duration, mantended free-flier missions for both the United States and international users."

John W. Anderson is an associate at the law firm of Wilson, Elser, Moskowitz, Edelman and Dicker in New York.

Disagreement over the free-flier issue caused the Europeans to miss NASA's March 10 deadline for a final commitment to participate in the station. NASA officials, however, have hinted that the Europeans may be backing down on their free-flier demand and conceding to build a module permanently attached to the station.

Yet the Europeans are not ready to abandon their free-flier idea. Aeritalia, the Italian aerospace main contractor that will build Europe's pressurized module, has recommended to ESA that the Europeans build two modules for the space station, the first attached to the station itself to satisfy NASA's demands and a second built as a free-flier to suit ESA's wishes. Aeritalia states that the second module would cost ESA only 10% more of its space station budget, from $160-180 million.

It is further anticipated that if ESA concedes on the free-flier issue, it would require the United States to concede ground on other thorny issues to be confronted later, such as proprietary rights and access questions (in other words, who can use what for how long aboard the station).

"We need to make some kind of mechanism that sets priorities to operate the space station such as when each group can use each of the elements on the station," according to Helen Kupperman, assistant general counsel at NASA. "There are many different ways to approach the problem—we haven't finished negotiations yet."

Negotiations are also still very active with the Japanese and Canadians. The Japanese want to build a laboratory module attached to the station. The problem with the Japanese is not what they want to build, but rather how much of the station they want to use once it is built.

The Japanese insist that at least 70 percent of the activities in their module are to be proprietary and any information gathered by the Japanese will be kept secret by encrypting the information back to Tokyo through transmissions or by transporting that same information back to Earth on the shuttle using portable memory disks.

NASA, however, has always operated on an "open door" policy, releasing almost all of its discoveries and experimentation, except in matters of national security. NASA's candor over the years originates from its charter devised during the Eisenhower Adminstration under the National Aeronautics and Space Act of 1958.

In that Act, NASA is instructed to "provide for the widest practicable and appropriate dis-

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semination of information concerning its activities and results."

Yet Kupperman says the Japanese request for secrecy can be met by NASA and does not conflict with NASA's charter. "We want to protect U. S. contractors aboard the station just as the Japanese want to protect their contractors," she said. "We will work out a situation where what belongs to the United States will remain with the United States and what belongs to Japan will remain with Japan."

The Canadians, however, have something else to say on this matter. Canada proposes to build a satellite servicing center on the station using the technology they developed with the remote manipulator arm for the shuttle program. The Canadians want to offer this service in a barter arrangement with the other international partners to receive in exchange information gained in material processing research—the very research the Japanese want to keep proprietary.

Thus, the law aboard the space station is far from settled. "We are still talking," Margaret Finarelli, NASA's chief international negotiator for the space station, said. "We are not even at the negotiation stage yet."

Final agreement on the station is not expected until spring, 1987, and there is still much to be resolved.

Aside from the contractual access problems, the international participants must decide what criminal code will apply, what the liability between the partners will be, and how legal problems arising aboard the station between the parties will be decided.

These questions will be left to a revolutionary new field in the area of law known as "astrolaw."

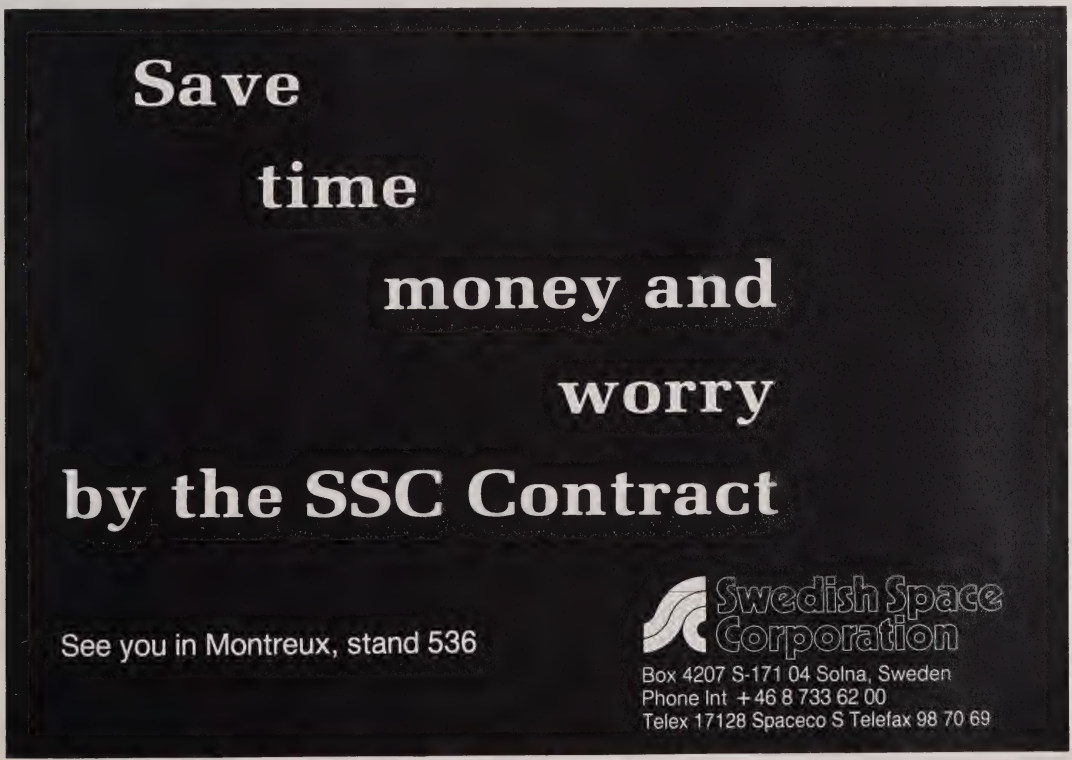
The term astrolaw is one coined by Dr. J. Henry Glazer, general counsel at NASA-Ames Research Center in Mountain View, California, which he describes in a recent law review article as "variegated applications of science and technology, in and for space, [which] will evolve into a helping profession."

An astrolawyer would reject completely the attorney's traditional role of an adversary fighting other parties in the battleground of a courtroom setting to instead take a role of mediator and problem-solver.

It is expected that such astrolawyers would one day be present on the station itself. Their daily assignments would be those of a technician performing various experiments, but they would resort to their legal skills when legal situations arise.

The astrolawyer's arena would be isolated and dangerous. He or she would therefore have to handle disputes quickly and equitably so that fights and other conflicts would be controlled for the protection of the crew aboard the space station.

The expediency of resolving conflicts on the station relates to its closed environment. Small disputes in cramped quarters can esca-



late quickly into major security risks given the physical restrictions of the space station. Control of the entire crew is necessary for the survival of all passengers.

Crewmembers will work side by side with each other for months at a time. Personal conflicts inevitably will arise. Hard feelings between crewmembers on the space station could brew into a terrible conflict if the crewmembers were not permitted to first resolve their problems amicably between themselves. The contestants should be permitted to articulate their concerns and take an active role in the resolution of their conflict so that any lingering hatred would be dissipated. It would be the astrolawyer's job, then, to regulate that steam in his role as a mediator.

Unfortunately, little research has been done on the role of the lawyer in space and no laws have yet been devised to dictate how law will be applied on the station.

Most research that has been done on the topic is strictly academic, such as trying to find the answer to where outer space begins, rather than dealing with the more mundane task of devising a workable legal structure aboard the station.

Such a system must be created, however, if a joint international space station linking the United States, Europe, Japan and Canada is to occur.

The plan is to create a legal scheme international in scope applicable to all its members, devising what some negotiators have termed a "new constitution."

Such a constitution would dictate the participation of each party involved and the guidelines each must follow in designing, developing and operating the station.

Perhaps the best way to describe the future role of an astrolawyer would be that of a nurturer. Laws applying to the space station must promote cooperation and comradeship rather than differences and division to assure cohesion of purposes between the parties.

Psychologists contend that the role of nurturer is best performed by women. The Soviet space program, for example, has stressed the importance of a woman present during long durational space travel because of her ability to act as a buffer between male crewmembers.

Back in the United States, the Drug Enforcement Agency found in a recent study that female agents tend to remain calmer than male agents during drug arrests.

National Public Radio, in a story on the DEA, reported that women also tend to relax the criminals they are arresting faster because women are not perceived as being as much of a threat as males.

This is not to suggest that all astrolawyers must therefore be female. Instead, it indicates that the nurturing aspect of a human being's character, which is traditionally found in women, must be enhanced by both male and female attorneys in order to resolve problems aboard

Little research has been done on the role of the lawyer in space and no laws have yet been devised to dictate how law will be applied on the station

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the station, problems that arise in very stressful situations.

Up to now, the legal problems being addressed in space station negotiations have dealt only with the economic, political and psychological ramifications of the space station. Hence, the State Department and NASA have been the major U. S. agencies that have been active in devising the space station plan.

But the United States has yet to address the military applications aboard the space station, which, "if the Department of Defense decides to use the station, there is no way NASA could not allow them to do otherwise," Kupperman of NASA said.

Currently, the Defense Department maintains that it has no use for the space station. In fact, the Defense Department has been a strong opponent of the station, claiming that funds used for the project could affect military space needs such as the Strategic Defense Initiative. President Reagan ignored Defense Department's arguments and instead approved the $8-billion project during his State of the Union Address in January, 1984, as a civilian endeavor left for NASA.

Yet Defense's involvement in the station at some level seems inevitable. As NASA's budgets have been slashed, the Defense Department's space program has increased steadily to a point where Defense expenditures for space activities now almost double those of NASA's.

The spread is expected to continue, which could result in the department having to pick up some of the expenditures for the station itself.

The Defense Department's increasing role in U. S. space activities can be shown in the recent announcement of the X-31 spaceplane.

Acclaimed by President Reagan as the second-generation shuttle or "Orient Express," the X-31's $500-million budget for 1986-88 will be paid almost exclusively by the Air Force, Navy, Defense Advanced Research Projects Agency and the SDI Organization, with only 20% of the budget coming from NASA itself.

The Defense Department contends that the plane is necessary for national security to assure easy access to space for military payloads. The spaceplane is expected to lower payload costs from the shuttle's $4,000 a pound to under $200 per pound.

More important to Defense's needs, the spaceplane can be refurbished quickly and relaunched for another mission.

The X-31 is expected to become operational by the mid-1990s, in time for initial operations of the space station. Because the X-31 is expected to be much more efficient than current orbiters, the spaceplane could be used to service the station, rotating crews back and forth.

But the spaceplane, developed in large part with Defense funds for Defense purposes, will be controlled by the Defense Department, thus creating possible problems for its use in space station applications. NASA officials, however, state that this does not create a problem, because the shuttle will service the station, and not the spaceplane.

"The spaceplane and shuttle are two very different beasts," Finarelli said. "The spaceplane will be used to move things from point to point very rapidly, while the shuttle is used for transport."

As to Defense's future role in the space station, Finarelli maintains that "the Defense Department has not identified any formal requirements for the space station. But they will continue to monitor the situation." ●

TRAINING LAWYERS IN ASTROLAW

WANTED: ASTRONAUT-ATTORNEYS FOR THE SPACE STATION

The field of astrolaw is germinating in the form of seminars at law schools across the country. The goal: to train lawyers to handle the person-to-person problems expected to arise in the confined space of the station.

Dr. J. Henry Glazer, a strong proponent of the subject at NASA-Ames Research Center in Mountain View, California, teaches a class on the topic at University of California-Hastings in San Francisco. A special program there, known as the NASA-Hastings Project, funds research in this new area of law, utilizing law schools in the University of California system for academic assistance.

One project involved sending select law students out to sea for ten weeks on the California Maritime Academy's training ship, the T/S Golden Bear, to simulate the closed environment of space.

The leading publication on the subject, the Journal of Space Law, is published by the University of Mississippi Law School in University, Mississippi.

Students at Georgetown University Law School in Washington, D. C., and the University of Houston Law Center in Houston, Texas, have formed "Space Law Groups" that host forums on the topic throughout the academic year. Both Georgetown and University of Houston law schools now offer space law courses for credit as well.

Astrolaw is a new branch of an "older" area of the law known as space law.

Space law is a field that analyzes the various idiosyncrasies of the five United Nations treaties that govern space activities of sovereign nations.

Astrolaw, on the other hand, incorporates those treaties established by the United Nations (such as the Outer Space Treaty and Liability Convention) and narrows their scope to create a legal structure that applies to the people living and working in space who represent the various nations, rather than being restricted to the nations themselves as space law is now.

GEOSYNCHRONOUS ORBIT

Burgeoning numbers of satellites and space debris in prime orbital locations are raising legal questions here on Earth

Barry Rosenberg/Washington

It has taken man thousands of years to crowd the Earth. But the prime geosynchronous orbit above the equator, the only place where communications satellites can be located without the use of costly tracking stations, is filling up quickly.

Engineers already see the almost infinite void of space becoming a traffic jam of communications satellites and debris 22,300 miles above the Earth.

Some nations, concerned that there won't be enough room left when they're ready to launch their own satellites, have begun to squabble with the United States. They believe the prime orbit locations are being hoarded.

Not true, according to U. S. officials. While there are some interference problems caused by satellites stationed virtually atop one another, it's attributed to poor operating procedures—not overcrowding. One industry consultant said that "people seem to be coping. They're accepting more interference and going to larger antennas."

Although the skies, especially above the United States and Europe, are becoming more crowded, the commercial future of geosynchronous satellites launches is secure. As long as the market demands it, ways have been and are being found to make space reusable. A burgeoning satellite and antenna technology will make it possible to at least double the number of communications satellites in the next decade.

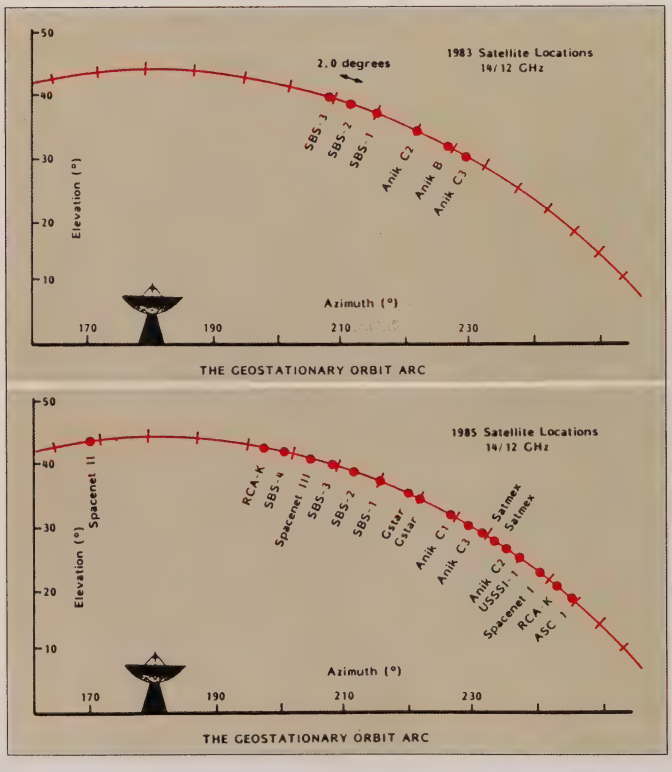
Participants in last summer's World Administrative Radio Conference conference in Geneva spent much of their time addressing the perceived overcrowding problem. The U. S. promises technological support for any nation wishing to enter the satellite communications market, provided geosynchronous orbit is reserved only on an as-needed basis. Prior reservation of orbital spots, however, is unacceptable to the U. S.

"Limits are set now by technology developed 20 years ago," Thomas Tycz, electrical engineer on the Federal Communications Commission Common Carrier Bureau, said. "We believe technology will continue to improve to always make space for somebody. In 10 years, the technology will allow increased capacity so we can eventually think about reducing the number of satellites."

Those in the private sector agree technology now permits satellites to be placed at the same orbital location. Concern is not with usable room in space, but with the inability to fine-tune uplink signals to avoid interference with nearby satellites, which are now being placed as close as 140 miles apart.

Mandatory spacing for domestic communications satellites exists only in the United States. The FCC mandated in April, 1983, that spacecraft be positioned two degrees apart because of dozens of pending applications. As of January, 1985, 110 satellites were undergoing preliminary registration with the International Telecommunications Union. They would join the 100-plus satellites now operating in the 6/4 and 14/11-12 GHz. bands. "Moving satellites closer together is the solution [to overcrowding]," Richard Shrum, State Department director of the Office of International Radio Communications, said.

But while technology permits closer spacing, it appears the knowledge to use the technology properly is lacking. The industry has begun po-



Barry Rosenberg moved recently from Florida to the Washington, D. C., area, where he is a freelance writer covering space and other topics.

IS RAPIDLY FILLING, LEADING TO A SCRAMBLE FOR SLOTS

licing itself to prevent interference, especially during live broadcasts of sporting events and the network's evening news programs. The networks aren't the hardest hit, though. Businesses such as banks and communications companies using low-power, low-speed data transmissions are often troubled by small, 300-400 watt stations manned by improperly trained technicians. Experts see the problem getting worse before the industry gains control of itself.

"The proliferation of transportable stations manned by improperly trained people is going to be a serious problem," Jay Ramasastry, vice chairman of the FCC's Two-Degree Spacing Advisory Committee, which consists of the major networks and other private sector transmitters, said. "If the antenna is not properly aligned, the signal is not going to the right transponders."

Satellite overcrowding is not strictly a geosynchronous problem. The orbital regime 250-310 miles high, reserved for scientific spacecraft such as the Solar Maximum observatory, and the orbit 500-570 miles out, which is the most suitable for Earth-imaging and weather satellites such as Landsat, are also experiencing crowding and debris problems.

However, the geosynchronous orbit is expected to receive the most growth and the most conflict in years to come. To prevent the need for tracking stations, communications satellites must be placed in orbit 22,300 miles above the equator. At that location, the satellite travels at the same velocity as the Earth rotates and appears to remain stationary. This allows the satellite to send and receive communications signals without the need for an intermediate Earth-bound communications network.

Interference from nearby satellites is a problem primarily for U. S. operators. They control the greatest number of satellites in geosynchronous orbit. Interference problems are expected eventually to occur between neighboring European countries, each operating their own satellites. Antenna technology to discriminate signals will have to improve to prevent such an overlap.

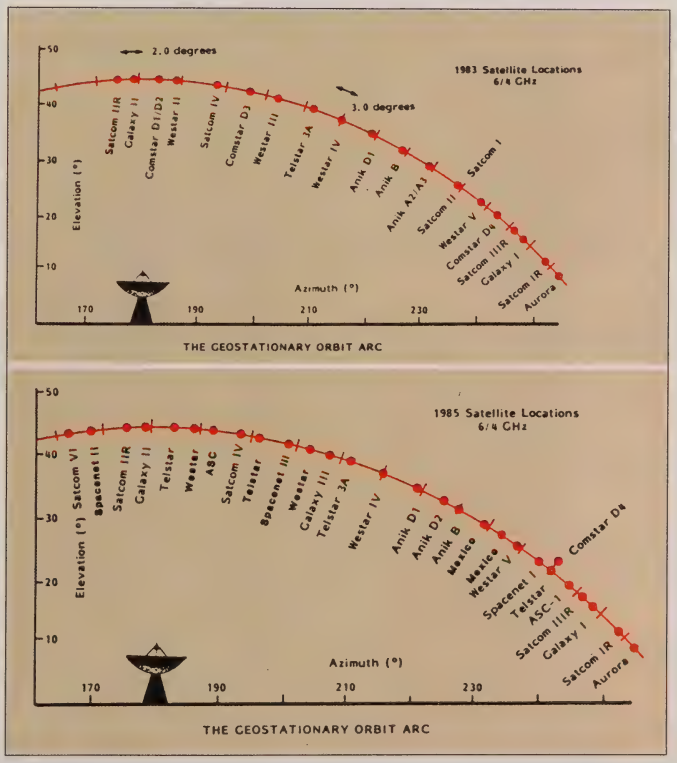
The Two-Degree Spacing Advisory Committee has developed several recommendations to prevent interference among satellites. The committee will recommend that antennas transmitting to satellites located within two-degree spacing meet rigid standards to prevent drifting of signals, and that transportable stations take signal pattern readings every time the station is turned on. A central monitoring point would have to approve an increase in power once the pattern is correctly focused. The committee also is examining the idea of assigning a transmitting code, or uplink identification, to every operating station. If interference results in a nearby satellite, the identification code could be used to determine the guilty party.

While advisors grapple with the issue of cooperation between transmitters and better training for technicians, space engineers have developed numerous ways to reuse space in geosynchronous orbit. Techniques that reduce the amount of interference between satellites increase the capacity of the orbit.

Recent technological advances that permit reuse of orbital space include:

- **Multiple Spot Beams**—Some satellites are capable of generating several spot beams that can be directed simultaneously at geographically distant receiving stations. As long as there is adequate distance between the stations there should be no interference among the beams. In that way, two or more satellites employing spot beams directed at properly spaced receivers can be placed in similar orbital locations.
- **Polarization Discrimination**—Radio

Growth in the number of satellites in geosynchronous orbit between 1983 and 1985 at K_U band is shown on facing page, and at C-band, in the drawing below.



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transmissions travel through space in two possible planes of polarization. The two planes are perpendicular to each other, which permits discrimination between the two within the same frequency band. Two satellites can operate within the same orbital space by having one transmit in one plane and the second operate in the other.

■ **Interference Cancellation**—As satellites crowd together, wanted and unwanted signals begin to merge. Theoretically, this can be corrected by developing a replica of the interfering signal and subtracting it from the signal received. The practice of interference cancellation is still experimental, but has prevented interference at intermediate and radio frequencies.

■ **Common User Systems**—Many countries have neither the technology nor the funds to develop their own satellite communications networks. Common user systems in which several nations share satellite resources allow these nations to obtain satellite communications without launching spacecraft for each individual country. The largest of these systems is operated by the International Telecommunications Satellite Organization. The cooperative provides international communications for 110 countries, and domestic communications for 26 nations, including 18 developing countries. The cost of operating Intelsat's 16 satellites is divided among all nations involved. Intelsat is managed by a private American company, the Communications Satellite Corp.

Numerous other common user systems exist. They include Intersputnik, which serves the Soviet Union, Eastern Europe and other Soviet-bloc countries; Arabsat, which serves 22 nations in the Middle East; Eutelsat, which provides some communications for Western Europe; Palapa, which serves Indonesia, and Inmarsat, a joint venture by the U. S., USSR and others to provide maritime communications.

■ **Frequency Development**—Two or more satellites can operate without interference from the same orbital location provided they operate at different frequencies. At present, most satellites in geosynchronous orbit operate in the 6/4 GHz. band, which was the first developed for commercial use. Only about two dozen satellites operate in the 14/11-12 GHz. band. Major news-gathering organizations are beginning to use the 14/11-12 GHz., or K_u-band, almost exclusively. Smaller antenna size and noninterference from microwave transmissions make it ideal for voice, data, business conferences and direct-to-home communications.

NASA, in a joint venture with private industry, is engaged in studies to develop frequencies beyond the K_u-band. The program, called the Advanced Communications Technology Satellite, is expected to alleviate the eventual crowding of the K_u-band. However, funds for that program are threatened by deficit reduction legislation. Hybrid satellites, used primarily by Intelsat, make use of both the 6/4 and 14/11-12 bands. They effectively double load capacity without increasing signal interference.

■ **Satellite and Earth Station Antenna Technology**—The more narrowly satellite transmitting and receiving beams can be focused, the more satellites can be employed in locations of close proximity. Satellite antenna technology has centered on multifeed and multireflector systems that provide shaped beams and little spillover of signals to unwanted receivers. Earth station antenna technology has focused on increasing the strength of the desired signals while decreasing unwanted signals. Methods to reduce erroneous signals are available even in low-priced dish systems.

The only real threat to future commercial marketing of geosynchronous orbit, other than interference, comes from the emerging technologies of terrestrial communication systems. Of those, fiber optic cables provide the greatest competition. Earth-bound fiber optic communication systems will take a chunk out of the satellite business, according to industry observers. However, for most nations, fiber optic communications technology is even more unreachable than satellite networks.

Fiber optic systems will take over about 12 percent of the satellite communications market, according to projections by the Communications Center of Clarksburg, Maryland., a telecommunications consulting firm. "But that little wound heals very quickly," Walter Morgan, company president, said. The areas most at risk by the development of fiber optics are those systems providing long-haul telephone service.

The only other barrier affecting the future growth of the commercial communications satellite market is the space debris unavoidably linked with increased numbers of satellites.

There is less than a one-in-a-million chance of collision resulting in satellite loss, according to experts, and it should stay that way for 20-30 years.

Between 80 and 90 trackable objects in low Earth orbit have disappeared in the last two decades. Most likely, the causes were either collisions or malfunctions. There is no proof to support either possibility, however. Scientists do believe that the Soviet satellite Cosmos 1275 was destroyed by a collision in 1981. The satellite disappeared from tracking screens and was replaced by hundreds of smaller, trackable fragments, according to Donald Kessler, Johnson Space Center project scientist for orbital debris studies.

The problem of debris in geosynchronous orbit is compounded by the satellites themselves. When satellites run out of fuel they drift about 3.3 degrees west each day. Eventually, they reach two stable points, or "graveyards," located at 75 deg. E. Long. and 105 deg. W. Long. After that, they stay there indefinitely.

Letting satellites drift through orbit increases the chance of a collision. Lately, operators, led by Great Britain, have begun saving a little fuel at the end of a satellite's lifespan to move the spacecraft into a higher orbit outside geosynchronous. "It's morally wrong to send satellites up and not think of their disposition," one researcher said. ●

In two or three decades, the amount of manmade debris in orbit will equal the number of background meteorite particles

NEW JOB FOR NASA IS MARKETING MANAGEMENT

Commercial competitors are waiting in the wings to play the role the bureaucratic space agency has so far been unable to handle

Mike MacMillan/New York

Growing internationalization of the space business has created a new imperative for NASA, one the agency may prove fundamentally incapable of managing. That imperative is marketing, in particular development of new commercial applications for existing or emerging technologies.

Hamstrung by bureaucratic inertia, the space agency has been slow to recognize and react to this shift in operating environment. As a result, competitors have been springing up to fill niches that NASA has so far been unable to occupy profitably.

In the 1960s and 1970s, NASA correctly perceived that its key constituency was not industry but Congress, and that the surest way to reach Congress was by courting public opinion, something at which the agency is an acknowledged expert. Hence the emphasis on manned exploration, culminating in the Citizen in Space program of which Christa McAuliffe was the most visible participant.

In those early days, NASA's relationship with its suppliers was much simpler. NASA was the customer, industry the contractor. With the advent of the shuttle, the first space technology expected to underwrite its own operating costs, that situation was substantially reversed. Today, NASA is charged with selling industry on the benefits of space-based manufacturing, and it must compete for scarce corporate R&D dollars with a host of terrestrial applications. As a result, the agency finds itself forced to pioneer new markets while overseeing the evolution of new technology and grappling with the complexities of the congressional funding process.

That NASA has not yet developed a strategy for coping with these new challenges is evident in the success of its competitors, Europe's Arianespace being the most frequently cited example. There are even some who believe that NASA's newly competitive operating environment was a contributing factor in the Mission 51-L accident.

"Everything I've read since the accident suggests that commercial pressure contributed to the destruction of the Challenger," Alex Roland, an associate professor of history at Duke University and a former NASA historian, said.

NASA, of course, is not the only U. S. organization to find its market share diminished by competition from abroad. And the agency has not been standing still in the face of threats to its primacy. NASA has created the Office of Commercial Programs to bear the responsibility for developing future markets in space. And though the lion's share of space agency budget continues to be spent on infrastructure, support for commercial applications is building. Funding for the Office of Commercial Programs doubled this year, to $17 million, and is slated for a substantial increase in 1987, to $31 million.

But in light of recent events, and the continued erosion of NASA's share of the satellite launching business, evident even before Challenger, the question remains: will it work?

The agency could be said to suffer from institutional schizophrenia, induced by fundamental contradictions in its charter, thanks to the 1984 amendment to the Space Act. NASA's original charter would seem to imply an R&D mission; the 1984 revised edition is heavily commercial. Some find this troubling. "My sense is that the charter calls for NASA to be involved in research and development," Don Stitt, the former president of General Space Corp. and now an industry consultant, said. It is his belief that the fifth shuttle, if and when it is built, should be owned privately. "It's time to begin privatization of the space transportation system," he said.

This isn't the first time General Space Corp. has advocated the privatization of the shuttle fleet. Stitt believes that the company could do a better job of marketing the shuttle than NASA. "General Space would like to do a lot of things Arianespace is doing that NASA, as a government agency, can't," Stitt said. Part of that would involve actively pioneering new markets. "The true value of the shuttle will show in materials processing and with the space station. These are whole new markets for which it is uniquely adapted."

General Space Corp. will soon have an opportunity to put its money where its mouth is, according to space agency officials. "NASA is preparing to solicit private interest in replacing the orbiter," Stan Goldberg, acting deputy director of the Office of Commercial Programs, said. "We'll resolve the issue [of privatization] that way."

There are still some who doubt NASA's capacity to effect the changes that will lead to greater market orientation.

"NASA made an administrative decision to be strictly an R&D operation. The shuttle experience suggests that the agency requires different institutional structures to handle the

Mike MacMillan is a free-lance writer living in New York.

two functions [marketing and R&D]," Roland said.

Others believe that the structures are in place, but doubt the commitment to commercialization on the part of NASA management.

"Senior NASA management has taken the commercial program quite seriously," Goldberg insisted. Still, he is willing to admit that things have not always proceeded as smoothly as he might have liked. "It would be naive to assume that, in an organization of 20,000 people, there aren't some mid-level managers who have their own programs in mind. But we're seeing a shift. Three or four years ago, some middle managers—primarily on the hardware side—didn't take the program seriously. All that's beginning to change."

Despite resistance from within NASA, and the reluctance of industry to commit large sums of money to space-based research, an infrastructure is slowly emerging. Companies specializing in space development and NASA-sponsored Centers for the Commercial Development of Space are popping up around the country. The centers represent NASA's effort to develop a working liaison with academia and private industry. But there are critics.

Roland suggests that the centers are "a desperate kind of promotion to find things to do with this vehicle in space. NASA has been fabricating hypothetical missions to have something to do with the shuttle, to build volume, to build traffic." Manned space flight, he believes, is being used as "a kind of loss leader" to attract continued funding.

"The shuttle will never be a commercial operation," Roland said. "It will never be competitive in satellite launching."

That is NASA's dilemma. The agency's only revenue-generating market is still maturing. The launch itself is becoming essentially a commodity item, with private industry making its choice of launch vehicles based primarily on cost considerations. The main difference between the shuttle and Ariane is that Ariane was developed using off-the-shelf concepts to fill a market niche, while the shuttle has been for much of its life a technology in search of a mission. As a result, the agency finds itself in a position where it must either develop new markets, a new vehicle or both.

The Centers for Commercial Development of Space are meant to be market incubators. Frank Jelinek, Center Director at Battelle Co-

U. S. intelligence sources estimate that a Soviet-designed space shuttle will make its first flight late this year or in early 1987, possibly before NASA can resume regular shuttle operations.

lumbus Laboratories in Columbus, Ohio, said that the "space commercialization centers are an investment to encourage industry to take a look at what can be done," and one of the cheapest ways to get industry involved.

NASA has great expectations for this aspect of its development program. Twenty-five proposals for establishing up to seven additional commercialization centers have been received. The selection cycle is expected to be completed by mid-June. A third cycle will commence next year after which NASA officials hope to have as many as 18 centers under way. Though the jury is still out, NASA seems to have found "a reasonable approach to getting industry involved in the commercial space program," Goldberg said.

Dr. Charles Lundquist is director of the Consortium for Materials Development at the University of Alabama, Huntsville, one of the five centers currently funded by the Office of Commercial Programs. The consortium was founded Oct. 1, 1985, and looks to field experiments promising a commercial return within five years. Researchers are concentrating on physical chemistry and material transport as it applies to crystal growth in a microgravity environment. The consortium receives $750,000 in annual funding from NASA, supplemented by industry contributions. Industry participants include GTE, Celanese and McDonnell Douglas.

Areas chosen for study include semiconductor crystal growth remote sensing, communications technology, biotechnology and space services. Each will have an industry/university investigator team. The university group is funded using NASA money; each industry must contribute $250,000 to its chosen project. The group had hoped to fly its first experiment this June under NASA's Getaway Special program. That now has been postponed indefinitely.

One possible scenario has the government setting up a separate agency to market the shuttle's capabilities in particular, and the idea of space-based industry in general, a technique the French have used with some success in the case of the Spot remote sensing satellite. The U. S. space marketing group might provide seed capital to start-up ventures, and fund long-range research. Once market opportunities were identified, it would be up to industry to move in and exploit them.

Goldberg maintains that a separate organization would accomplish little that NASA isn't already doing. The expertise for integrating and flying payloads is already resident within NASA, he said. Turning the marketing function over to the private sector is possible, but not very practical, according to Goldberg. "A private company could buy the necessary expertise, but I'm not sure how they would make a profit."

Lundquist, for one, sees no conflict in NASA's dual role in R&D and marketing. "If one looks around competitively at what other nations are doing, the U. S. has to put together partnerships between government, academia and industry," he said. "We can't compete with the Japanese and the French if we continue to have an adversarial relationship between these factions."

Another source of friction between NASA and private industry has been the availability of space in the shuttle. Though the agency has floated a number of proposals for getting industry into orbit, its good intentions have often been belied by the massive amount of paperwork required prior to flight.

Henry Owen, a public relations specialist at 3M Corp., believes that it is the role of government to encourage industry to develop new uses for the shuttle because the government is "the only one running a space program right now." He said that 3M's relations with NASA are "excellent. In nine months we went from handshake to first flight."

Others have found their dealings with NASA less pleasant. "Any company that has the misfortune of dealing with NASA runs into the inevitable culture shock that occurs when a private company and a government agency interact," one industry observer said.

Many believe the barrier is institutional. "There must be the willingness [within NASA] to have evolutionary change, to make modifications where needed," Lundquist said.

Others are more blunt. "When you deal with NASA, everything must be checked up the line," one observer said. "The person you're dealing with may not have the power to make decisions. While he's talking to you, he's also sniffing the air to see which way the political winds are blowing. It happened with the shuttle and it's happening now with the space station."

But Goldberg insists that things are changing, and that the process of applying for a Joint Endeavor Agreement is becoming easier. "We have prepared a joint agreements manual outlining criteria and providing a model agreement. If the language we've developed regarding third party liability, patent and data rights, and so forth is accepted by the applicant, the project review can now be completed in as little as a month."

Space Industries' fly-now, pay-later arrangement with NASA is the closest the agency has come to an enlightened marketing policy. However, the requirement that these flights not make a profit is hard to understand.

That the term market driven can be applied—however tangentially—to some of NASA's activities is a sign that things are changing within the agency. However, there remains much work to be done, both in developing markets and in creating merchanisms that will allow companies large and small affordable access to space. In this, NASA is just starting up the learning curve. Some of its experiments will no doubt fail through organizational resistance or simple wrongheadedness. But others will succeed and provide the foundation for new organizational structures and a new relationship with private industry. What is required, more than anything else, is a willingness to adapt. That is the one consistent message—simple but inviolable—of the marketplace. ●

A space marketing group could provide seed capital and fund research, but once identified, it would be up to industry to move in and exploit marketing opportunities

BACK TO BUSINESS: EXECUTIVES IN THE PRIVATE SECTOR SPEAK THEIR MINDS ABOUT SPACE COMMERCIALIZATION

John J. Egan/Washington

The parameters and terms of private participation in the space station project are rapidly becoming important issues.

As communications satellites have been launched and as companies such as McDonnell Douglas, 3M, John Deere and others have developed and flown commercial experiments, the roles of private firms as customers of the shuttle have become defined. Once NASA's current difficulties are overcome, there is reason for optimism that business will continue as a customer of the shuttle, and eventually of the space station laboratory modules. Commercial satellite companies may well avail themselves of a variety of services that could be provided on the space station.

We know that private companies including Space Industries, Inc., are now proposing to develop, own and operate free-flying platforms for the use of commercial customers. But what about the possibility of private development, ownership and operation of actual space station facilities? Would business be interested? Would our international partners agree to this? What would it mean for NASA?

NASA asked Coopers & Lybrand to examine these questions. The firm identified the fundamental premises of this undertaking and, with these in mind, developed a hypothesis and a list of questions regarding the conditions under which business would be willing to make such an investment in the space station. The hypothesis was tested and questions asked in interviews with twenty U. S. companies.

The first assumption is that providing opportunities for commercial ownership and operation of space station facilities will enhance its capabilities, augmenting those provided by NASA's capital investment.

In considering which portions of the space station could be available for commercial ownership/operation, the researchers took as a given that NASA must retain the central role in developing and operating those portions that are essential to its safe operation (such as emergency power, emergency life support, stabilization and orbit maintenance). They also assumed that NASA would begin by asking business which facilities could be owned and operated commercially, and would then assume responsibility for the remaining functions. With the help of space station program managers, the researchers prepared a list of likely areas for commercialization.

Two key premises are that NASA could assume long-term financial commitments of a kind that might require legislative changes and that NASA could modify its mode of operation to assume the role of customer. As customer, NASA would monitor the design, assure integration of services and evaluate performance. NASA would, in effect, be issuing franchises through a competitive process for certain space station operations while maintaining minimal control.

The researchers assumed that NASA's international partners would be willing to accept such commercial involvement if they were guaranteed equal treatment with NASA with regard to prices charged, penalties imposed and access accorded, and if foreign industries received opportunities and treatment equal to that of U. S. industry for participation on non-U. S. facilities. They further assumed that their commercial involvement would not result in a reduction in government funds already committed to the space station.

The hypothesis was that under certain conditions, U. S. industry would be willing to make a commercial investment in ownership and operation of space station facilities. Basic to this hypothesis is the assumption that U. S. businesses believe that such a project will be of value to their companies, that the risks involved can be understood and are manageable, and that there is a market of sufficient size to generate adequate revenue.

The researchers interviewed senior management from companies representative of industries that might be interested in such a venture: communications, data management banking, hospitality, power, project management/construction, space transport and related services, and waste management. They interviewed only a few of the major aerospace companies because their answers might tend to be self-serving given their present role in space station development.

The researchers' interviews indicated that the hypothesis was essentially correct. U. S. business is indeed willing to consider a venture involving ownership/operation of space station facilities, provided that government can give solid assurance of the market for services and a reasonable return on

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Note: This is not a complete or official list and will obviously change significantly.

John J. Egan is director of the Commercial Space Consulting Practice, Coopers & Lybrand, Washington, D. C.

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their investments. The answers indicated further that space projects would be evaluated like any other investment opportunity but that non-revenue issues are also a major factor. Such issues include entree for the company into a new market, exposure to new technologies, and the public relations potential of the project.

The following is a sampling of questions raised in these interviews, and relevant replies.

What is the minimum amount of risk protection and revenue or long-term contractual agreements that your company would require from the government in such a venture?

"The technology risk can be managed—it's been done before. The business risk is high because the market is unknown."

"In the short run, NASA and people like ESA are the entire market—we'd have to be assured of their business."

"If the government is willing to enter into binding contracts to use the services provided, we see this as a very attractive opportunity."

"An exclusive franchise is the first assurance we'd require for becoming involved. We'd expect to compete for it, but, once we had it, we'd want to make our own business decisions."

How would a space project fit into your company's evaluation process?

"Such a project is a business deal. It has to meet the same criteria used to evaluate all undertakings."

"The intangibles will be important to the decision—there has to be more value to the deal than just a return."

"I see such a project as a way of learning something."

What are major stumbling blocks to your company engaging in such a project?

"It will take a major change in NASA's way of doing business to do this—we would like to see it happen but, to be honest, we're skeptical."

"Tax incentives would help, but they wouldn't make the deal."

Are there impediments to the success of such a space venture over which you feel your company has no control?

"The government could cancel a program at any time. We can't invest without assurances that they will honor their contracts despite cancellation."

"NASA will have to set standards and do acceptance testing and leave the builder alone to do his work."

U. S. companies are interested in establishing viable businesses on the space station. They do not believe that their commercial involvement in the space station will require business practices that are out of the ordinary.

They clearly recognize that in the early stages of this evolutionary process, commercial participation involves considerable market risk. Thus they want franchises to protect them from competition in what they view as a limited market and governmental agreements to compensate for delays, changes in requirements and cancellation. They are willing to accept penalties for their delays and errors; they ask only that NASA agree to do the same.

To meet the conditions U. S. business requires for its participation in ownership and operation of space station facilities, NASA will have to make major adjustments in its way of doing business and assume considerable responsibility for reducing market risk.

Clearly, important changes will have to occur for private development, ownership and operation of station facilities to become a reality. But Coopers & Lybrand has shown that U. S. business is very interested in the proposition. ●

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MOVING ON:

NASA'S SHUTTLE TEAM HAS WORK TO DO WHILE THE ORBITER FLEET REMAINS GROUNDED

The space agency's 'can do' shuttle team is now vowing: 'never again'

Edward H. Kolcum/Cocoa Beach, Fla.

National Aeronautics and Space Administration and its space shuttle contractors are teaming not only to find and fix the cause of the Jan. 28 Challenger accident, but also to establish procedures to eliminate the possibility of a reoccurrence.

The destruction of orbiter Challenger along with the loss of its seven crewmembers was followed by a period of discouragement, demoralization and uncertainty on the part of management and the rank-and-file contractor work force. Managers began to bicker among themselves; the technicians that had prepared twenty-four shuttle systems that achieved orbit were abruptly accused of shoddy workmanship, and the previously sacrosanct image of a "can-do" NASA was buffeted with charges of flawed management. A pall of dejection enveloped the 16,000 employees here who depend on the space program for their livelihoods. They justifiably feared that the space program was in jeopardy.

This postaccident era will never end for some, but it has eased with time and with the firm commitment by the United States to get on with the space program as soon as possible.

But how do you keep a skilled and experienced work force togther when the job for which they are paid—processing space shuttles for launch every few weeks—is on hold? The standdown period could last a year or perhaps more because NASA, Congress and the public will not allow expediency or quick fixes to dictate the pace of the space program in the future as they have, at times, in the past. And from a commercial standpoint, what economic justification is there to maintain the payrolls for what could be an indefinite nonprogram?

These are not easy questions, but the logic that has gone into the answers could be useful to any high-technology commercial venture suffering a setback.

Lockheed Space Operations Co., which won the hotly contested shuttle processing contract in September, 1983, and NASA managers who supervise the contract, have come up with a comprehensive plan designed to use the standdown time in a way that will refine every facet of preparing shuttle hardware for launch. This includes an overhaul of deficient paperwork, a recertification of every engineer and technician, the introduction of simulators for training and cross-training individual workers so they can assume other tasks when there is a shortage in a skill not their own.

J. A. Thomas, director of shuttle launch and landing operations, and David S. Dickenson, vice president and director of Kennedy operations for Lockheed, are convinced that, given the current overtime constraints, the processing work force is as busy as ever and can be just as productive.

Normal shuttle processing calls for seven-day, three-shift workweeks. The average technicians were on the job 45 hour weekly, and some were peaking at 50 hour. Currently, the force is on a five-day workweek with two daily shifts. Orbiters normally are not powered except on the first shift. There is some third shift work, but it involves very specialized duties, Thomas said. Weekend work normally calls for small crews in hazardous-duty operations.

L. H. Yount, vice president and director of Kennedy support operations, said he uses three shifts seven days, but most of the third and weekend shifts are used to "baby-sit" systems and be available in emergencies. Thomas said that overtime for the entire shuttle processing contract has been reduced to less than 1 percent from 16-17 percent prior to the Challenger loss. Since Feb. 1, overtime has been in the 2 percent range.

"I've been with Lockheed thirty-three years and I've never seen the dedication that I do with the people here," Dickenson said. "These guys want to be here [when shuttle flights resume]. That's dedication to the shuttle program."

A challenge that comes with a long standdown is "keeping people from getting discouraged," Dickenson said. A significant step in overcoming discouragement, he believes, will occur when NASA provides a definitive work statement. This will be based on the report of the Presidential Commission on the Challenger Accident to be completed in June.

Immediately after the Challenger accident, Lockheed and NASA conducted exhaustive investigations of everything done at Kennedy to process shuttle hardware.

Eventually, the work was broken down into six categories:

- Orbiter modifications.
- Orbiter testing.
- Paperwork cleanup.
- Ground equipment and the processing and launch facilities.
- Training.
- Support of the Challenger investigation.

Additionally, NASA established a plan that will enable the work goals to be reached with a minimum of overtime and still put the complete system in the "top drawer when we fly again," Thomas said.

Columbia will be transferred to Vandenberg AFB, California, mid-July to function as a path-

finder vehicle for shuttle launch facilities being completed there. Columbia is the oldest of the shuttle orbiters, and, of the three remaining in the fleet, requires the most modification work, including 100,000 man-hours to install more advanced silica tiles to protect the vehicle from the heat of reentry. Every two to three years, each orbiter undergoes a lengthy structural inspection, and Columbia is being examined during the standdown.

The pathfinder function will help assure that the equipment at Vandenberg is compatible with shuttle flight hardware. Columbia will be as close as possible to the flight configuration so that most of the testing can be conducted during its temporary stay there.

The Vandenberg launch site will be used to place military satellites into polar orbits from which every spot on the globe can be observed once every 24 hours. The Kennedy launch site is used to place satellites into East-West and geosynchronous orbits. The shuttle carries payloads into low Earth orbit about 150 miles up. From there, the satellites are lifted into 22,300-mile geosynchronous orbit by self-contained upper stages.

Discovery is the spacecraft that will be permanently stationed at Vandenberg. It is being modified here to handle the Centaur upper stage. Centaur is used for heavy spacecraft, up to about 10,000 pounds. The USAF/Boeing Inertial Upper Stage (IUS) can loft about half this weight, and the McDonnell Douglas payload assist module (PAM) is able to lift about 3,000 pounds.

Other modifications to Discovery involve about 18,000 man-hours of work on the protective tiles.

Atlantis was being processed to carry scientific probes bound for Jupiter at the time of the Challenger accident. The shuttle system was destacked in April and May to investigate the seals in its solid rocket booster joints, because a faulty seal between the lower solid booster segments is considered the most probable cause of the Challenger explosion.

Tile work on Atlantis will consume an estimated 20,000 man-hours. Atlantis has been structured to carry the Centaur stage.

Other orbiter modification and testing for Atlantis involves Centaur "match-mate" to be certain all Centaur hardware is compatible with the orbiter.

James A. Harrington, Thomas' deputy, said that, in regard to documentation, "there has been a lot of negligence. For example, it is necessary to have a quality control stamp before you pick up a disconnect, and the stamp may not have been there. It could be that the inspector simply failed to stamp the document, even though the item in question was certainly disconnected."

"We haven't found anything that would have contributed to the accident, but it is a bad trend on the part of NASA and the contractors, primarily the contractors," he said. "Maybe people just didn't understand the total documentation process, but we're cleaning up."

Thomas added that paperwork deficiencies were "a complete surprise to us. It is not anything we were alarmed about because we thought our paperwork was close to being infallible. We thought we had some rules and regulations that we just couldn't misunderstand."

Dickenson said that although Lockheed was working on a number of improvements prior to the accident, the company's own internal investigation since Jan. 28 has turned up some documents "where the date could have been in the wrong place or it could not be understood. We know the people who wrote and worked [the document] understood it, but to a third party coming in it was difficult to understand."

Both NASA and Lockheed are placing considerable emphasis on training, particularly in the firing room where consoles are located and operated.

Thomas said that a NASA engineer learning to launch the shuttle has, in the past, picked up his skills by reading manuals and looking over the shoulder of an experienced operator. Kennedy now wants to exploit its considerable computer capability by extending it to simulators, much like the practice in Mission Control at Johnson Space Center.

"We are also going to take this standdown opportunity to cross-train our systems engineers so that, for example, a fluids man in one group can learn another fluids system so that when we get in a manpower crunch he can fill in," Thomas said. "We are going to recertify all our people, from technicians to quality control to top-level managers."

Since the Challenger accident, there has been a 10 percent reduction in the work force by Lockheed and its main processing subcontractors, Grumman and Morton Thiokol. All layoffs had been planned as part of the experience process developed in two and a half years of shuttle launches and because work on a third mobile launch platform has been completed. Shuttle orbiters, solid rocket boosters and external tanks are assembled on reusable mobile launch platforms that are moved from the vehicle assembly building to the launch pad. After launch, the mobile platforms are moved back to the assembly building or a nearby parking area. ●

A challenge that comes with a long standdown is keeping people from getting discouraged

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R&D UPDATE

Jeffrey Manber/New York

CRYSTAL GROWN ON SPACELAB 3 DISPLAYS SUPERIOR TRAITS

EG&G Energy Measurements, Inc.'s, final report on its Spacelab 3 shuttle mission concludes that the mercuric iodide crystal grown during the mission does display superior electronic characteristics. EG&G is under contract with the Department of Energy to improve methods of radiation detection, and mercuric iodide detectors are believed to be more practical for portable detection units.

The detector performance of the space crystal is compatible to the top 2 percent of Earth-grown crystals, according to Carol Ortale, who is studying the crystal. The rate of growth of the mercuric iodide was 300 percent faster than expected.

For now, explains Ortale, EG&G researchers will concentrate on redesigning crystal furnaces to produce better heat transfer and less convection for growth on the ground. But, "it does help our long-term objectives to know we actually can grow better crystals in microgravity." ●

GERMAN ROCKET PROGRAM PROVIDES SIX MINUTES OF MICROGRAVITY

The West German TEXUS program continues to offer researchers an invaluable six minutes of microgravity environment via a Skylark 7 rocket. The TEXUS (Technical Experiments Under Zero Gravity) program has flown twelve missions, and two more are planned this spring.

The Skylark 7 carries a payload of experimental modules to an altitude of 270 kilometers. Upon completion of the flight arc, the nose of the rocket, containing the experiments, is parachuted back to Earth. The experiments can be controlled by telemetry and monitored from the ground.

Advantages include relatively low mission costs and short preparation times for the launch, as well as the ability to use materials deemed too hazardous for shuttle missions. The upcoming missions will focus on metallurgy, crystal growth and biological research. Investigators include those from Germany, Belgium, France, Italy and Japan. The Japanese experiment will focus on producing super-conductive materials with near-zero resistance.

Over half of the D1 shuttle/Spacelab experiments that flew last fall were first tested in the Skylark rockets. Also, as a reflection of the maturity of microgravity research, an increasing number of upcoming TEXUS experiments will be more concerned with applications-oriented projects, rather than basic research. ●

3M FILES PATENTS BASED ON SHUTTLE EXPERIMENTS

The 3M Co. has filed the first patents based on data derived from its experiments flown on three shuttle missions. Though purposely vague to protect the patent data, Dr. Chris Podsiadly, director of the 3M Science Research Laboratory, did report that NASA was recently sent a report detailing the filing of the patents. The report is prepared to partly fulfill the requirement under the current two-year joint endeavor agreement with NASA, which states that 3M must begin to disclose results one year after the research takes place.

Covered under the patent filings were data obtained during the diffusive mixing of organic solutions (DMOS) experiment, as well as from the physical vapor transport of organic solids (PVTOS) project.

The DMOS patents also include information gleaned from ground-based crystal work, but Podsiadly expects additional patents to be filed in the near future relating solely to the shuttle-based crystal growth. ●

GRUMMAN PLANS TO EXPLORE GALLIUM-ARSENIDE PRODUCTION IN SPACE

Grumman Corp. in Bethpage, New York, plans to sign an agreement with Ethyl Corp. of Richmond, Virginia, for a joint research and development project to explore the production of electronic semiconductor material in space. The chief material to be investigated will be gallium-arsenide crystals.

Grumman has undertaken a major shuttle research program towards development of industrial crystals through a process known as directional solidification; it flew its first shuttle experiment on the 51-G mission in June, 1985.

Ethyl's Morgan Semiconductor Div. in Garland, Texas, is an established manufacturer of gallium-arsenide crystals and semiconductor wafers. "We are looking to Ethyl to lend its expertise in producing the crystal and in helping us market the final product," explained Lou Hemmerdinger, program manager for Grumman's space program unit. ●

SHUTTLE, NO MIR, MAYBE . . .

The grounding of the shuttle fleet has created a growing line of frustrated corporate, university and entrepreneurial microgravity researchers. For many of the researchers, faced with intact funding and marketing plans but no space shuttle, the publicity surrounding the launch of Mir, the new Soviet space station, has given rise to a wistful scenario of East-West cooperation in space. Though the possibility of non-communist use of the Soviet space station is slim at best, it does reflect the extent to which shuttle users are seeking continued access to space.

3M Co. officials commented soon after the launch of Mir that "we would not be surprised to hear from the Soviets regarding use of their station for 3M's corporate research." Would they accept? "That I'm not sure."

John Graham, director of microgravity applications with Canadian Astronautics, Ltd., in Ottawa is also hoping for Western use of the Soviet space station. CAL is expected to fly on a 1988 shuttle mission to explore perfecting a technique of putting clusters of insulin-producing cells into microscopic capsules for treatment of diabetes.

Graham has had no communication with Soviet space officials and said that he hasn't "thought through the potential of the relationship that would be involved. My thought," adds Graham, "is simply that the Soviet space station is there and the U. S. space shuttle is quiet."

Another organization musing the possibilities is the University City Science Center, a NASA Center for Excellence. William Claybaugh, vice president for the space division, said American use of the space station is "an intriguing possibility that has occurred to us." Adds Claybaugh, "If the Soviets were to approach with a reasonable offer, it would be seriously considered." ●

Jeffrey K. Manber is editor of the Space R&D Alert, a newsletter covering ongoing commercial space research.

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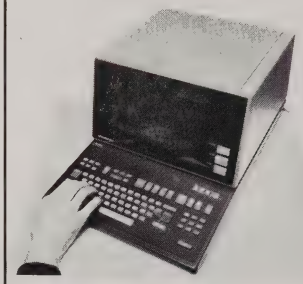

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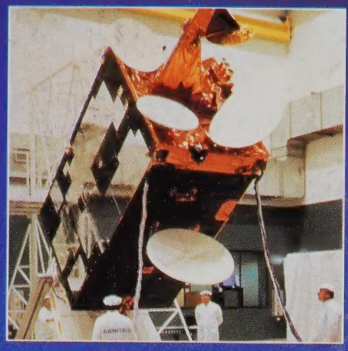

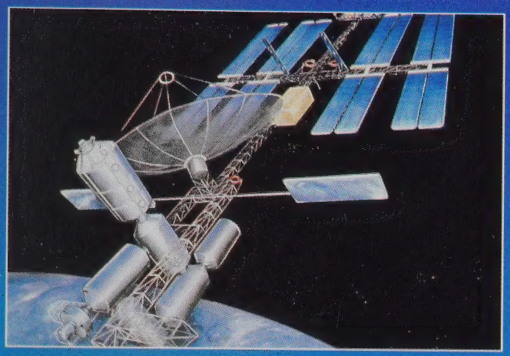

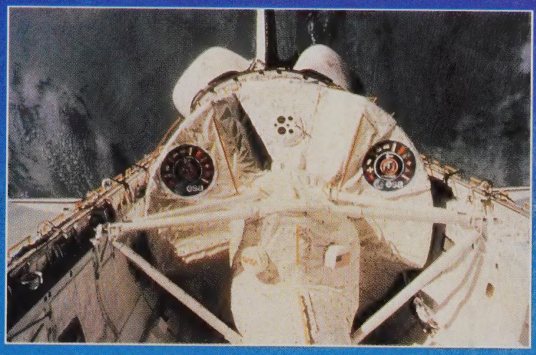

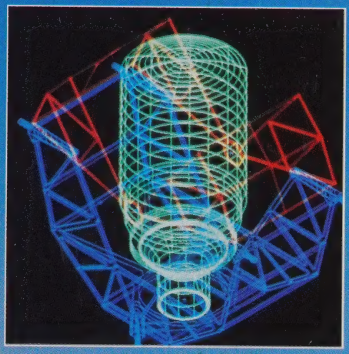

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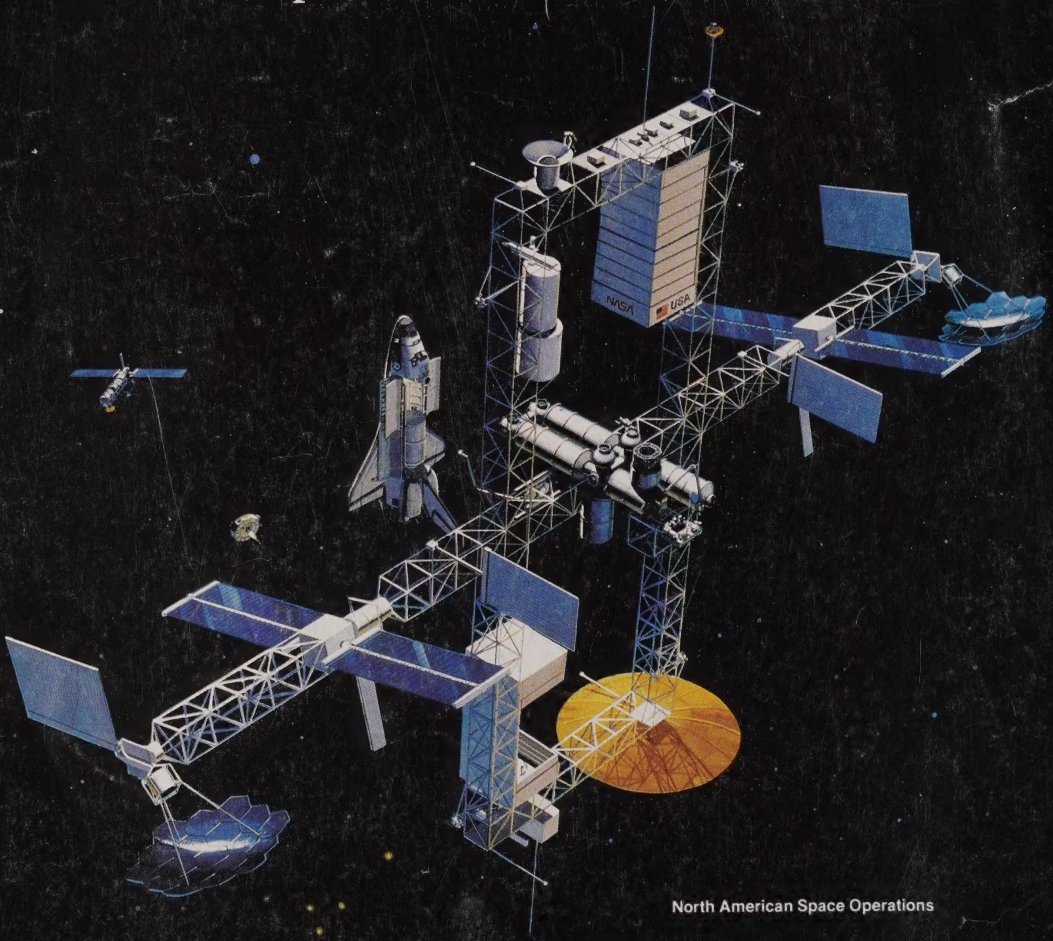

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